VOL. XXXVIII. — No. 12. DECEMBER 1961.

Monthly Bulletin of the International Railway Congress Association

(English Edition)

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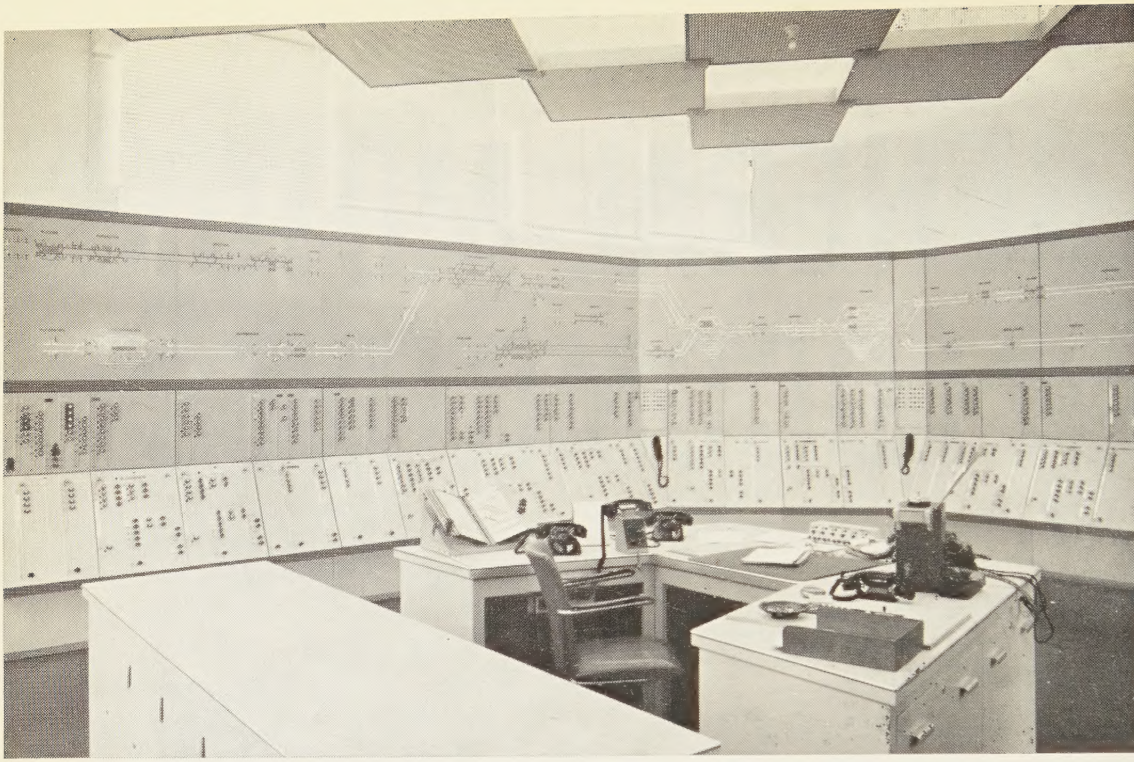

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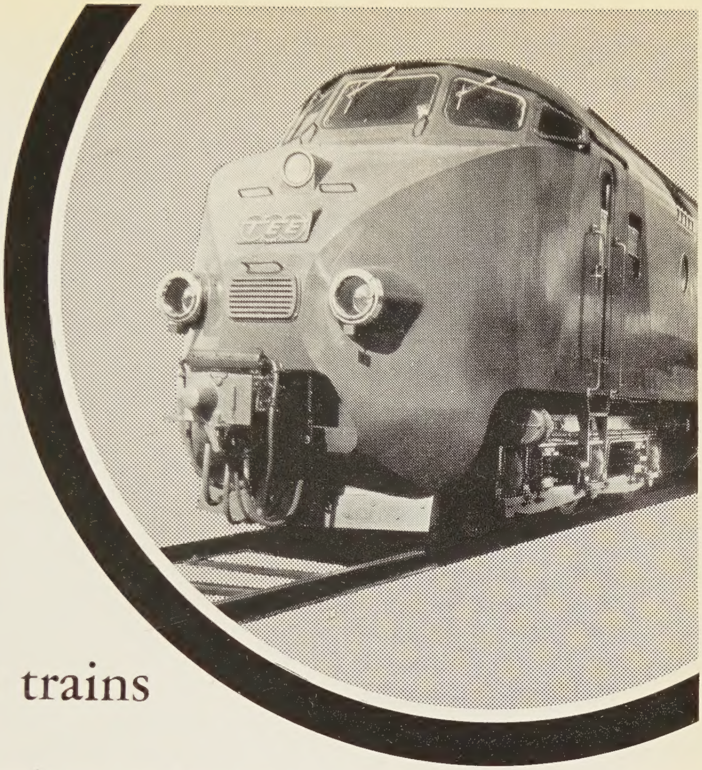

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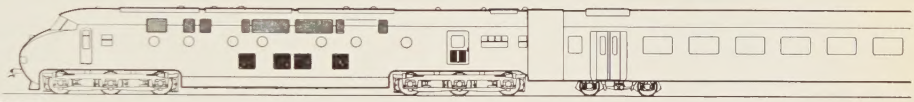

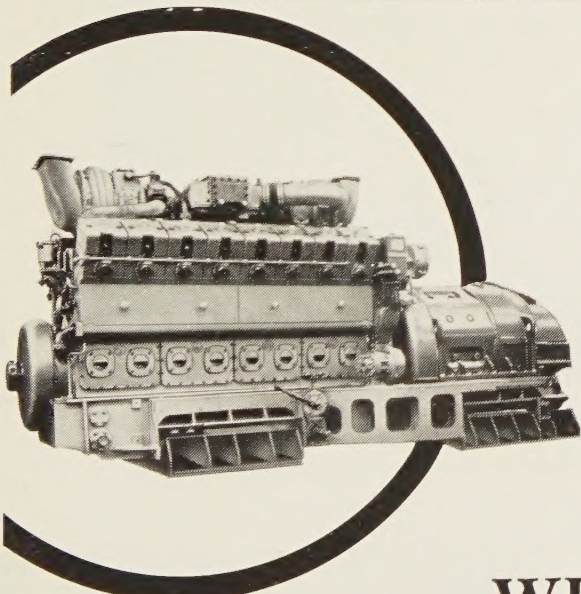

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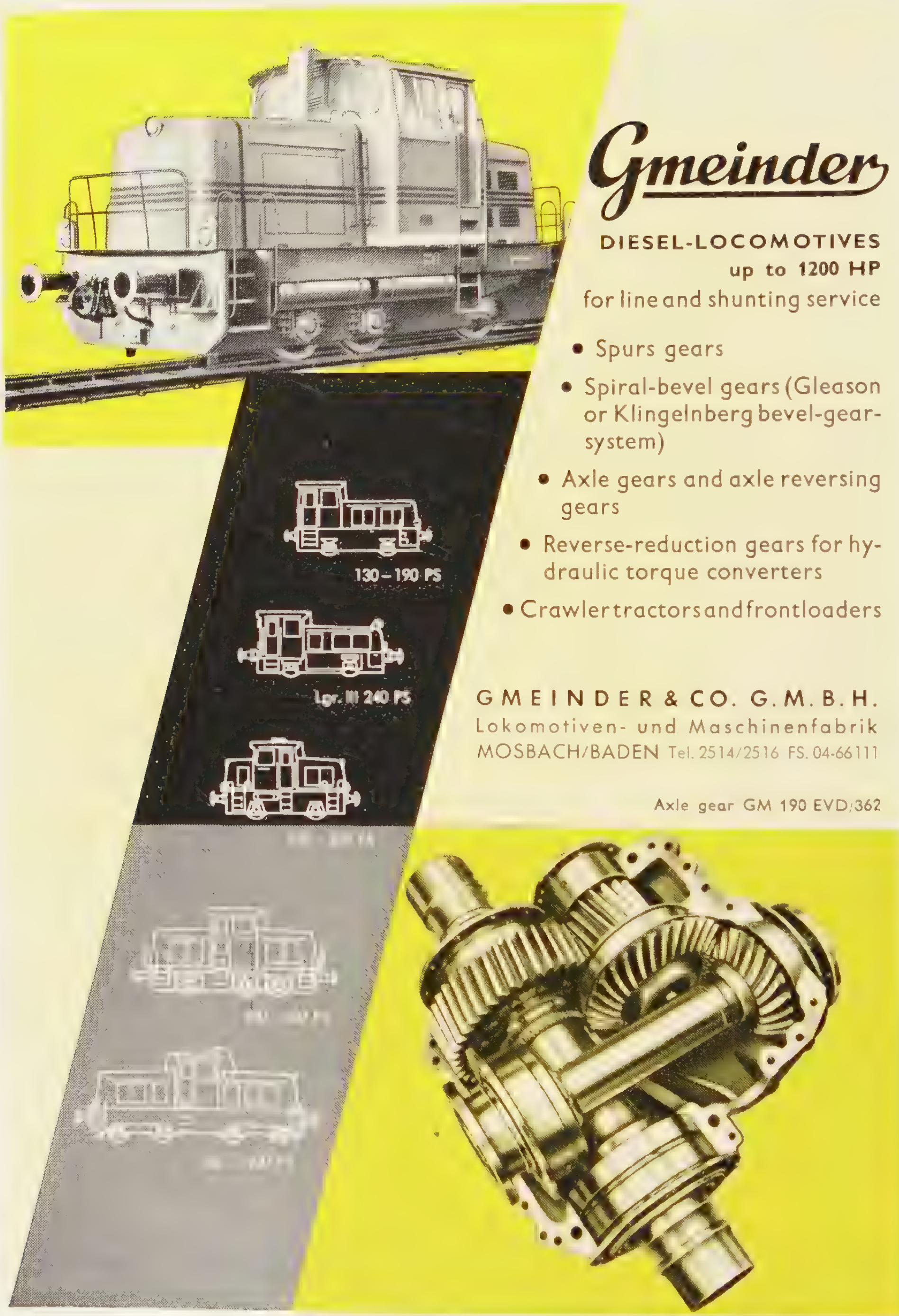
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MONTHLY BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(ENGLISH EDITION)

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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656 .25]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

18th SESSION (MUNICH, 1962).

QUESTION 2.

Means of reducing the final cost of signalling installations by standardization or other methods, including the use of electronics and other modern techniques.

REPORT

(America (North and South), Australia, Burma, Ceylon, Egypt, Finland, Ghana, India, Indonesia, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, Philippines, South Africa, Siam, Sudan, Sweden, Union of Socialist Soviet Republics, United Kingdom of Great Britain and Northern Ireland and dependent overseas territories),

by A.W. Woodbridge,

Chief Signal and Telecommunications Engineer, British Transport Commission, British Railways Division.

Introduction.

In the years since the conclusion of the second World War many railway systems, faced with keen competition from other forms of transport or indeed, in a number of cases with a rapidly rising traffic, have had to look carefully at the equipment they had in use. For many of them there was a long period during which no appreciable re-equipping was possible either from financial or other reasons.

It was evident that on many railways much re-equipping would have to be undertaken and that the signalling systems employed must have a high priority on the list of assets to require modernisation. Unfortunately it is a fact that modern signalling equipment is relatively expensive material to purchase and install. The justification for its use is in the fact that it enables the remaining railway assets such as rolling stock, locomotives, permanent way and also certain grades of staff such as signalmen and train crews, to be used in a much more efficient way and in this manner it produces financial savings in a number of different directions.

The Signal Engineer of any railway is very conscious that money spent on signalling material, while being of a highly reliable standard, should not be extravagantly used either in quantity or quality. The phrase « final cost of signalling installations » in the question must therefore be examined from the overall point of view of the intrinsic value of the equipment itself, and the use to which it is put.

It must be assumed that the railway organisations are adequately controlling the quantity of signalling equipment that is used or it is proposed to install and there-

fore the interpretation of the question has been directed mainly towards that side of the subject under the direct control of the Engineer. Such a question as this has not been discussed on any previous occasion and does come at a very appropriate time when many organisations are spending large sums on signalling and more automation.

In view of the great variation in signalling practices throughout the world and the local conditions which influence costs installations similar in size in the various countries cannot be compared directly with one another and the general reaction of the concerns with regard to the questions will be reported on and summarised.

Signals.

11.111. *What is the system of signalling in use on main track?*

The replies of all the countries show that under modern conditions the signalling system adopted is based on automatic or semi-automatic colour light signals where it is understood that the automatic signal is controlled solely by the passage of the trains and the semi-automatic signal is one in which the signal is both controlled by the passage of the trains, but has means whereby a signalman or other responsible official can control the aspect shown by the signal.

Most countries in the British Commonwealth are using two, three, or four aspect systems of colour light signalling, the aspects generally following the same pattern as shown in figure 1 :—

Through interlockings, in most British Commonwealth countries, the signalling over diverging junctions is done either by means of a route indicator which displays the name of the road to which the movement is to be made, e.g. Main, Slow, Platform, Siding, etc., or by means of a junction indicator comprising a row of lunar white lights pointing to the diverging direction and mounted above the main signal. The former are used for slow speed movements and the latter for higher speeds or running diverging junctions.

Other organisations, notably the U.S.A. and New Zealand, have adopted signalling aspects which generally speaking indicate the speeds at which the locomotive driver should run.

The Egyptian system has adopted a five aspect system which uses a three aspect light signal in the following way :—

1. *Green* for Proceed at Normal Speed.

2. *Green flashing* for warning the next signal is yellow.

3. *Yellow for Caution,* be ready to stop at the next signal.

4. *Yellow flashing* to indicate that the speed at which the next signal can be passed is either 30 km per hour or the speed indicated at the top of the signal.

5. *Red* for Stop.

The U.S.S.R. has adopted three and four aspect signalling to control movements on

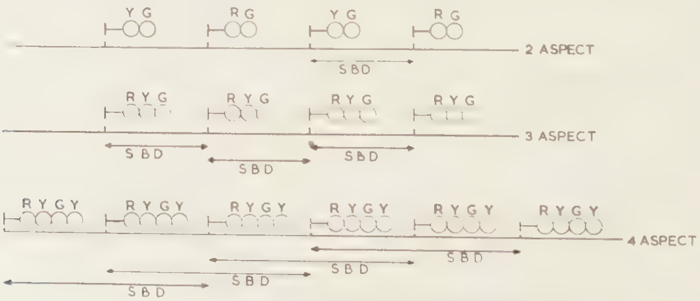

Fig. 1.

open main lines while at station or interlockings movement from a main to a secondary line is controlled by two yellow lights, a warning of the turnout being given in the preceding signal by a yellow flashing light.

In the Scandinavian countries the home signals at each interlocking, when necessary, give aspects which indicate a reduction in speed for turnouts, etc., while the block or starting signals are simple two aspect, red or green. Flashing lights are used for distant signals in Sweden or Norway to indicate aspect of the home signal.

A number of organisations employ a combination of signal aspects which convey to the driver an indication of the speed at which he is expected to run. These include the railways of U.S.A., New Zealand and Japan.

It can thus be considered that modern practice amongst the English speaking group of nations is to adopt the colour light signal as a standard using the three basic colours, red, yellow and green in various combinations. It is not clear, however, why there is the necessity for a wide difference in the number of aspects devised and adopted by the various countries and it would seem that simplification might be possible in a number of directions.

There are various methods of keeping records of the trains passing in use on the different railways, and among these are automatic train recording devices and train describers. Both the latter are expensive and are justified on the density of traffic to be handled and the working requirements of the trains.

11. *What is the system of signalling in use.*

11.112. *On loops?*

Most countries adopt a similar system of signalling on loop lines as they do on main lines. A few, however, have not found any necessity to modernise this signalling and have left the older system in use, for example, India has two position lower quadrant semaphore signalling on such lines and does not propose to alter it in the near future. Others do not provide any signalling in such lines.

All countries that employ modern signalling on loop lines provide it to a standard which is necessary to meet the local traffic conditions and the requirements of safe working.

11. *What is the system of signalling in use.*

11.113. *In sidings and shunting yards?*

Much of the cost of a modern signalling installation lies in the provision of fully signalling shunting moves. Where these movements are frequent and have to be carried out quickly and safely it is the general practice in many countries to provide shunting signals at a large number of point connections, the shunting signals being operated in the same way as main running signals. The general practice everywhere is to provide full interlocking on these signals and to ensure that all points are detected correctly in position.

Such requirements are met with at major interlocking plants, but at smaller and less important installations some countries do not use shunting signals, but they do use controlled signals at the entrance to and the exits from sidings and shunting yards. Inside the shunting yards themselves it is the exception to find the movements fully signalled. There are, however, installations to be found in Great Britain where this is necessary. In Japan, where shunting is carried out without a shunter attending, shunting signals are provided, but where a shunter is in attendance, shunting indicators convey to the shunter the move to be made.

In America the yard switching (or shunting) system is in use and is an arrangement whereby the route is established by remote control from a control centre. Such systems may or may not be provided with fixed signals at the points.

In the majority of countries it is now the practice to use dwarf signals of the position light type for shunting purposes; the signals,

in most cases, make use of lunar white aspects for giving permission to move and for stop, a lunar white and a red. It is no longer the practice anywhere in modern signalling installations to use a ground signal of a type similar to running signals or to use point indicators.

11.114. *What advantages over the old system have been obtained by the introduction of the new system?*

Due to the particular time in history of railway development, the application of modern signalling in various countries has not been uniform in all parts of the world. Thus in some countries the need to reduce the overall cost of conveying traffic by rail to maintain the existing position had led to the development of systems of signalling whereby the overall quantity of assets has been drastically reduced. Recent years have seen the widespread applications of Centralised Traffic Control in America, for example, as a means for carrying existing traffics over single lines instead of the previous double lines and in particular the New York Central Railroads' reduction of four tracks to two.

Other parts of the world have found that by spending money on modern signalling where a primitive form previously existed, the existing lines would carry much more traffic and consequently under the pressure of increasing traffic it has not been necessary to increase the number of tracks with the consequent heavy structural and earthwork problems.

Thus in the railway world there are two major trends in which modernised signalling is providing a means of keeping down overall costs :—

1. In those countries where road and air competition is very great.
and

2. In those countries where traffics are developing rapidly.

The advantages which are claimed for the modern systems of signalling are :—

1. Increased safety by increase in equipment to safeguard trains.

2. Train movement is expedited.

3. The territory controlled from a central point can be enlarged when required.

4. Traffic can be handled better and with greater flexibility.

5. Traffic staff can be reduced.

6. Track capacity can be increased and a greater density of traffic handled.

7. Standardised indications by day and night.

8. Improved operating performances with lower operating costs.

9. Higher average speeds can be maintained and thus service is speeded up.

10. Seasonal fluctuations in traffic flows can be catered for more easily.

11. The installations are cheaper to maintain.

12. Signal aspects are easily seen in all conditions of visibility.

13. Fog signalmen not required.

14. Simplification of signal aspects.

15. Reduction in the human element controlling trains with consequent reduction in the risk of accidents.

It is noteworthy that all countries claim economies in operating staff are worthwhile even though there may be no problem of shortage of manpower.

12.121. *Have you adopted the automatic block system? If so, please describe the fundamental principles.*

As a means of increasing the track capacity, where this is required, all countries have introduced the automatic block system. Some countries have used it successfully on both double and single lines, but many have only used it on the former. It is the general practice to control signals by means of track circuits, although the methods differ between systems. It does not seem to be a common practice to control the various signal aspects by means of coded track circuits as was the tendency a few years ago; in fact the modern tendency is to use the simplest types of track circuit for this pur-

pose. Where, however, as on certain lines in the U.S.A. and U.S.S.R. cab signalling is in use on the locomotives, the coded system is retained. There is, of course, a limit to the use of cab signalling through complicated interlockings with many subdivisions of the track circuits, as the cost of coding equipment becomes very high.

The Japanese National Railways are, however, installing what is known as Type A cab warning system in automatic block territory. This consists of an inductive pick-up on the locomotive for receiving a carrier frequency of 1 300 c.p.s. modulated by two low frequency codes, 20 c.p.s. and 35 c.p.s. This modulated carrier frequency is superimposed on the 50 or 60 c.p.s. current which is used for the normal A.C. track circuits. The 20 c.p.s. current is used to indicate in the locomotive cab that the automatic section has a « clear » signal while the 35 c.p.s. current is transmitted, when the section has a « caution » aspect. Under the first condition a white indicator lamp shows in the cab while with the latter the indicator shows a red light and a bell is sounded, warning the driver that the signal he is approaching is at « stop ». If the train passes the « stop » signal and enters an occupied section, the code current transmitted from the signal ahead is shunted by the train occupying the section and results in a flashing red light in the cab indicator and a buzzer sounding. This equipment is also designed to be an automatic train control if required.

In Great Britain the intermittent type of automatic warning system devised by British Railways is being applied to all running signals of the colour light type whether in controlled or automatic block territory on the main lines.

The intermittent type of warning system is also applied on lines in the U.S.A. in accordance with the standard requirements for the equipping of railroads with safety devices.

Single tracks equipped with automatic block signals exist in a number of countries and generally where the single line is divided into a number of sections in either direction Absolute Permissive Block principles are adopted. Usually these sections are integrated with Centralised Traffic Control; indeed, where reversible working is adopted on double tracks, this form of control becomes essential.

The Swedish, Rhodesian, and Burmese Railways have adopted approach lighting of signals by track circuits in some instances, the two former on their single lines and the latter on double lines. Generally speaking it would seem that approach lighting is no longer widely adopted as a principle.

The « Stop » and « Proceed » rule is not applied on British Railways, having been discarded some years ago after one or two accidents. The abolition has necessitated the introduction of telephonic communication on private wires between all automatic signals and the signal box in advance, and also to the indication of the condition of all block section track circuits in the signal box ahead. The British Railways also practice « Signal proving » in automatic sections, that is, a signal must have been showing a red aspect before the signal to the rear of it can clear automatically. (See diagram.)

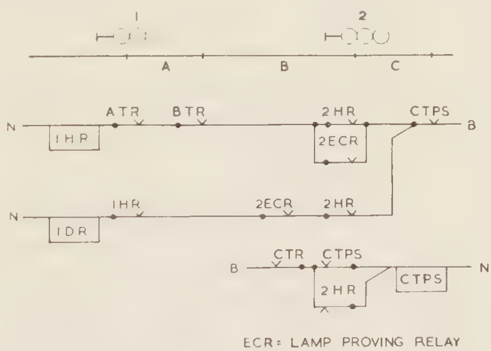

Fig. 2. — Signal proving in automatic block section.

In Sweden the interlocking in a section is done by utilising one pair of wires in the telephone cable for each line of way. Track circuit relay contacts are inserted in this pair of wires and two control currents are

used, one at 36 V D.C. and the other 50 V A.C. Assuming that the required direction of traffic is South to North, then the A.C. will be fed South to North through the section from the entering end and the D.C. fed from North to South. The two currents are separated in the block equipments by means of filters. The D.C. is used to control the relays which operate the signal aspects; a source of D.C. supply is provided at each stop signal and means also provided for changing polarity at track sections in the rear, so that the appropriate aspects can be shown on the signals. The A.C. is used for proving that track circuits are clear and that the opposing starter is at « stop ». The A.C. is only supplied at stations and is also used to determine the direction of traffic. This is done automatically simply by the clearance of the signal allowing entrance to the single line section which, of course, requires the track circuits to be clear.

12.122. *What is the length of the minimum overlap for different types of signals and for different speeds?*

The question of whether or not to provide overlaps at Home signals or automatic signals has been the subject of considerable discussion in the past, particularly when it was originally introduced on British Railways, and goes back to the days when few vehicles were fitted with continuous automatic brakes. In many other countries since that time the continuous automatic brake has been fitted to all vehicles, whether passenger or freight and in Great Britain, where freight wagons were in general unfitted, a greater number are being equipped. It therefore becomes a general question as to whether or not to provide overlaps to stop signals with the additional track circuits and control which are then required. Also, with the wide range of speeds which is now encountered on all railway systems, whether any variation to the length of overlap was made to accord with the maximum speed of the line in question.

In the U.S.A. and Japan on lines outside very dense traffic areas it is unusual to provide overlaps of the type mentioned, other countries do not have overlaps at automatic block signals, but do provide them at Home signals for interlockings. Most countries provide overlaps at all Home signals in two aspect signalling territory and at all signals in multi-aspect systems. These overlaps are in general standard distances and are not related to train speeds or type. New South Wales has a rule that the overlap is to be equal to the braking distance of the highest speed freight train (taking into account gradient and maximum authorised and attainable speed for the location concerned) plus 30 %.

The lengths of the overlaps when provided vary from about 200 yards for multiple aspect signalling to a value of 440 yards for two and three aspect signalling. Norway still works to a full block overlap which is a minimum of 1 km.

On Japanese lines with very dense traffic where signals are closely spaced for headway purposes an overlap of about 50 m is standard at all signals.

Great Britain and Egypt are at present contemplating modifying the present practices with regard to overlaps. In Great Britain this is a result of the present programme for fitting the automatic warning system on all important lines and of the equipping of freight wagons with continuous brakes.

13.131. *What is the normal form of the signal units (home, distant, block, shunting signals) and has standardisation been aimed at for all their component parts (arms, lamps, lenses, etc.)?*

There is a selection of colour light units for main signals in use in the various countries, but in general all the countries are aiming at standardising on one particular variety. The main choice of such signals at present rests between :

1. *Multi-lens signal heads.*

These are made up into one, two, three,

four or five lens units complete and are used for Home, Distant, and Block signals, whether the system of signalling is for two, three, four or five aspect signalling.

2. « *Searchlight* » *type signal head.*

The searchlight type of signal, which has an integral relay operating mechanism for moving a spectacle with three colour filters (red, green and yellow) in a beam of light, is essentially a signal for three aspect signalling or speed signalling, based on three aspects, and is used for Home, Distant and Block signals.

In Great Britain, where four aspect signalling is the standard for main lines, the searchlight type is being discarded as it is not considered to possess any advantages over the multi lens type of signal head, except for very special purposes.

3. *The single unit, built-up type.*

In this type of signal head, each lens unit is built as a standard unit and the number of aspects to be displayed is made up by building the required number of these units into a frame.

The materials used in the construction of these units varies between cast iron, light alloy and plastic. So far experience has not shown any price advantage in the use of any of these materials.

The lenses themselves have become standardised by the general use in all countries of 8 3/8" diameter for the main signal units of all three types mentioned above. If a smaller unit is required the general standard is 5 3/8".

For shunting signals there is a general tendency to use a position light type of signal built up of standard units. Most of these use two lights, lunar white and red horizontal for « Stop », and two lunar whites at an angle, 45° or 90° to horizontal for « Go »; in other cases a white light is substituted for the red in the « Stop » position. The U.S.A. still use colour light units of the type used for main running signals.

A large variety of electric lamps exists for use in the various colour light and position light signal units, but not much information has been supplied regarding the use of this particular item. It is noteworthy, however, that all countries are making efforts to standardise the types used, although it has not been stated what the future standard might be. In view of the precision type of lamp that is required, it is felt that this should be an item to be dealt with as first priority, and the only information available is as follows :—

Country	*Main signals*	*Position light*
Sweden	12 V, 24 W, spherical bulb, bayonet cap.	55 V, 20 W, spherical bulb, bayonet cap.
Egypt	12 V, double filament, (No other information.)	
Japan	30 V, 40 W, double filament, multi-lens type.	10 V, 20 W.
Great Britain . .	12 V, 16/24 W, tripole multi-lens type, 3 pin focussed cap.	110 V, 25 W, bayonet cap heavy duty commercial type.

13.132. *What is the normal form of signal carrying structures (riveted or welded rolled sections, tubes, concrete) and have these structures been rationalised?*

When colour light signals are erected at the side of the track a steel tubular mast of 5 1/2" or 4 1/2" diameter (or a similar metric measurement) is used in many countries. In two cases, Norway and Rhodesia,

the tubes are galvanised to reduce maintenance. In most cases the lengths of tubes have been standardised with the object of keeping the signals as near the drivers' eye level as possible.

The U.S.S.R., Japan and Sweden are using concrete poles in certain cases and in the latter country the concrete pole is superseding the tubular mast entirely.

In cases where a tubular signal mast cannot be used, cantilever and bridge structures are used mostly fabricated from rolled steel sections rivetted together. The rivetting is considered to be more advantageous than welding, although one or two cases of welding are reported.

For electrified lines, both Sweden and U.S.S.R. mount the colour light signals on the catenary structures, but other countries are using separate structures and the colour light signals are suspended in cages from the cantilever or bridge boom.

The New Zealand Railways make their cantilevers and signal bridges from welded rolled steel sections supported by hardwood poles.

13.133. *What methods have been adopted for the erection of signals (bases precast or poured in situ, holes excavated by power augers, etc.)?*

It is not often found that tubular steel posts are planted directly into the ground, but it is more usual for a cast iron base to be fitted to the base of the tube and this is bolted on to a concrete foundation which may be pre-cast or the concrete poured into the foundation hole in situ. Most railways today use the pre-cast type of foundation for tubular signals as these can be produced in quantity at a central depot and then distributed to site. For the larger structures such as long cantilevers and signal bridges it is usual to pour the concrete in situ.

A few railways use a train specially equipped for concrete mixing and pouring and under an engineering occupation of the track form the foundations of a whole series of signals, the holes having been previously dug. This is done in Japan and on some sections of British Railways.

The foundations of dwarf and position light signals are usually pre-cast in most countries.

Manual methods of excavating the foundation holes are used as a general rule in most countries, but Japan and New Zealand now do most of this work by means of power driven augers. To a certain limited extent similar means are used in the U.S.A. and Great Britain.

14. *What point operating mechanisms and connections (including the methods of locking the points) do you use and what are their advantages over the old? Please give a short description.*

There does not seem to have been much change in the methods of operating points over a considerable period of years. The predominant method is to use proprietary designs of combined point operating and locking mechanisms in which the switch detector contacts, the facing point lock and the throwing mechanism are in one case mounted on the sleeper ends. Again, the predominant motive power is the all-electric machine; the electro-pneumatic drive is apparently considered to be obsolete. Many types of electric point operating machine are available for both direct current and single phase alternating current operation.

The Swedish Railways use a machine of Swedish design and manufacture which has a trailable feature incorporated, but it seems that there is no tendency for the trailable feature to be extended to other countries.

The U.S.A. report very little change in their machines over a considerable period and only a few refinements such as are required to reduce frost interference and simplifications for interchangeability for use with right and left hand switches.

Japanese Railways have now brought into use a combined all-electric point machine for which it is claimed :—

1. The weight is about two-thirds (300 kg) of the old types.

2. The point control relay is housed inside the machine instead of in a separate case.

3. The locks are separately arranged for the normal and reverse positions, making adjustment easier and safer.

4. The price is also about two-thirds of the older pattern.

In Great Britain, where there are three large makers of signalling equipment, proposals for arranging the rod connections for point drive and detection to standard types are in hand.

Generally speaking there does not seem to be any apparent great move for simplifying and cheapening designs of point operating mechanisms.

15.151. *What type of insulated rail joints do you use? Does it give satisfaction from an economic point of view?*

For many years all railways used an insulated joint in which the steel fishplates were separated from the web of the rail by sheets of fibre insulation bent to fit the web, the fishplate bolts being insulated from the rail by fibre collets and the two ends of the rail by an end post of approximately the same shape as the rail section.

This type of joint, while it gave good insulation properties when in good condition, did not last for any appreciable period of time if traffic was heavy and consequently the maintenance and renewal cost of such joints is heavy.

Over a period of years fishplates made of resin bonded laminated beechwood have been developed and are gradually proving to be more economical than previous types of fibre insulation. Most countries using them have reported favourably on their use for general purposes; there are one or two reservations where the permanent way may be subject to excessive strain.

At the present time the main problem is to find an improved material for end posts. Experiments are proceeding in Sweden with a nylon material (skulon), in Japan with nylon material and a polycarbonate material and in England with rubber compound material. No results are yet available except that the rubber material in England is now being put to extended trials.

15.152. *Have you already replaced or do you plan to replace the track circuits with insulated joints by other devices, e.g. H.F. circuits?*

The track circuit of the traditional type using either D.C. or A.C. has been the foundation of all modern forms of signalling since its invention in 1872 by Robinson, and over this period by the development of newer materials and designs; while the apparatus has been refined and improved in itself it has not changed much in its fundamental principles.

The track circuit has, however, one major defect arising from its very nature. It is unreliable if the contact between vehicle tyre and rail surface is not good and of low resistance; this can come about by the rail or tyre surface, or both, becoming of high electrical resistance and also if light weight vehicles moving at speed are run over them. The question of the bad contact has received a considerable amount of study in recent years and the high voltage impulsing track circuit has been evolved using electronic circuits to provide these impulses. In one or two countries this type of track circuit has been used with considerable success, but there is no general tendency to make use of them in place of the normal track circuit.

In Japan, however, audio frequency track circuits are being adopted on 50 c.p.s. A.C. electric traction lines as being more economical in both first cost and running as compared with the 83 1/3 c.p.s. A.C. track circuit.

Audio frequency track circuits of the so-called « Overlay » type are being used in a number of countries for special purposes such as ground frame releasing and for detection purposes at level crossings controlled by automatic barriers.

In Great Britain where it is planned to use long welded rails on the main lines

audio frequency track circuits are being adopted on those sections where track circuiting is necessary. The type used does not require any insulated rail joints. The same type of track circuit is being adopted for those areas where there is D.C. traction with rail return. On these lines A.C. 50 c.p.s. track circuits are used with heavy impedance bonds. There is a very great saving of money in these cases by the elimination of the impedance bond.

15.153. *Do you use axle counters and under what circumstances?*

At the present time the axle counter is the only alternative to a track circuit under certain circumstances, but where track circuits can be used it has not proved to be a serious rival. It is only used where track circuits cannot be provided economically, for instance, where steel sleepers are in use or the ballast resistance is extremely low. They are also used for recording track fullness in large marshalling yards both in the U.S.A. and Great Britain.

At one time, with the advent of the concrete sleeper, axle counters looked as though they might have to be developed to a greater extent than previously. However, the problems of using track circuits on lines with concrete sleepers have been solved and there is no further need to proceed along this line of development.

16. *What types of rail bonds do you use and what are the methods for fixing them?*

There are two principle methods of bonding rail joints at present; by welding the bonds or by pinning the bonds to the rail. Both methods are employed in most countries, but the pinning method seems to be the one in most use. It is felt in Great Britain, for example, that in the event of a bond breaking the pinned type is easier and cheaper to renew than a welded type.

On all electrified lines, except the A.C. electric lines in Great Britain, short bonds are welded on to either the rail head or foot and are of flexible copper of a suitable section to carry the traction return current to the rails. In Great Britain, the A.C. traction return rail is bonded with three copper wire bonds (No. 8 swg.) on the web of the rail and two similar bonds on the other track circuit rail. These bonds are pinned to the rail web.

Similar bonds either copper or galvanised iron wire (No. 8 swg.) are used all over the British Commonwealth.

The use of power drilling machines is now common everywhere and these may have one, two, or three drilling heads, as required.

2. Cables in the field.

21.211. *What kinds of cables are used for working signals?*

Some countries are still using oil impregnated paper insulated, multicore, lead sheathed, armoured and jute served cables for this purpose, while many others have adopted the newer forms of cable with plastic insulation and sheaths. In few instances the latter types may also be armoured for mechanical protection purposes.

There is still some use made of lead sheath, plastic insulated cables, but not to any great extent.

These later forms of synthetic cables do not require the services of highly skilled plumber jointers as did the older lead sheathed type and are consequently more convenient and easy to install with signal installation staff.

The conductor sizes, thickness of sheath and insulation is standardised in each country and in all cases use is made of standard ranges of numbers of conductor depending on the use to which the cable is put.

21.212. *What kinds of cables are used for working points?*

The types of cable used for point operation are similar to those in use for signal operation with the exception, of course, that the conductor cross section may in some cases need to be higher.

It is in the conductor cross section that the effect of operating voltage is felt and no doubt the high voltage three phase point motor scores in this respect, as compared with the lower voltage D.C. and single phase A.C. point motors.

In these cables also, there are standard ranges of types and sizes from which the user may choose.

21.213. *What kinds of cable are used for working track circuits?*

In general the type of cable used are similar in specification to those for signals and points, but there is a wide divergence of the particular type used in each country, although mostly the basis is plastic insulation. Some railways, for example, use single core cable and a number of others twin cable, each of these may be found in armoured and unarmoured types. Unless there is a good reason for adopting the armoured form, it would not seem to warrant the extra cost for this purpose.

In nearly all cases a stranded type of conductor is used for the track circuit cable.

22.221. *What kind of main cable route do you use (buried, in troughs, etc.)?*

It is the practice of nearly all countries to bury the cables on main route directly in the ground at a depth of approximately 3'0". Indeed the use of cable troughs has become obsolete except for use in yards in Japan and certain sections of British Railways. South Africa, Southern Ireland and parts of British Railways still use concrete stake routes, but others only use these under special circumstances.

Few railways use cover tiles for their buried cables and Sweden and parts of British Railways do not use armouring as a protection on buried cables.

22.222. *Are mechanical means used for laying the cables? Please describe.*

With the use of buried cables or troughing laid with the lids flush with the surface of the ground there is always the possibility of mechanising the actual preparation of the cable route. Some obstructions may inevitably be met and these have to be dealt with by manual methods.

In the countries where there is space, use is being made of power driven trenching machines which are usually self propelling and sometimes equipped for back filling. Some machines of the type are found in U.S.A. and Australia.

In many countries, however, it is not possible to use machines of this type on the railway formation and therefore machines have been devised for working from specially designed railway vehicles. Sweden, Norway and New Zealand have methods for using a rail mounted cable plough, which is pulled along by a locomotive. The cables are fed through tubes at the back of the plough and are laid as the plough progresses. The New Zealand design lays three cables at once and proceeds at about 4 m.p.h. (See photograph fig. 3.)

On British Railways it was found that the plough was unsuitable and in many cases could not be used when, as was generally the case, the trench was required at some distance from the centre of the track and in addition, the plough was difficult to design for use on embankments or the sides of cuttings. Another form of machine has therefore been devised.

Track maintenance machines such as ballast cleaners, tampers, etc., are now used to a great extent in Great Britain and their use precludes most obstructions underground within a few feet of the track. The machine devised for British Railways is rail mounted and a bucket chain is mounted on a cantilever structure which will dig a trench 18 inches wide and to a depth of six feet at a maximum distance of ten feet from the running face of the nearest rail. The trench can be dug in cuttings or on the sides of embankments without the need for special adjustments. Digging speed depends a great deal on conditions, but in good going a forward speed of 10'0" per minute is attained. The machine is self-contained and winches itself forward. Floodlighting

Fig. 3. — New Zealand Railways cable plough, blade raised after completion of breaking up run.

is self-contained for night work. (Fig. 4 — photograph.)

Other countries are still excavating the trenches throughout by manual means, but are using specially equipped wagons for carrying the cable drums and laying out the cable.

22.223. *Are plastic insulated cables purchased in standard or in especially made lengths? Why? How are they joined?*

Some years ago it was considered that a cable joint could be a weak spot in an otherwise good system of electric transmis-

sion and no doubt had some foundation of fact to support this view. It was then the endeavour of the signal engineer to run the cable as far as practicable, without jointing lengths together, between the signal box and the function to be operated, or to terminate one length in a pot-end mounted in a lineside case and then to jumper across to another pot-ended length of cable. Thus no joints were made in cables in the cable run. This necessitated special cable length lists being made out and the manufacture of special drums, etc., together with added complication to the organisation for laying the cables.

With the improvement and perfection of cable jointing techniques these methods have now almost universally been discarded and most railways are ordering their cables in standard lengths depending on size and weight of cable, and jointing them together as required. Those standard lengths vary from 440 to 1 000 yards and sometimes more. The reasons given for the procedure are as follows :—

Fig. 4. — Trench digger at Reading, British Railways, Western Region.

1. Cables can be purchased in quantity.

2. Stocks of cables can be held.

3. It is more economical.

4. Simplifies the purchasing and storage problems.

5. Detailed planning of cable requirements not necessary.

6. The stock of cable is controlled better.

7. The cables can be ordered independently of the works to be done.

8. The supplying of specially made lengths of cable can cause considerable delays in the carrying out of works, it is therefore advantageous to be able to draw from stock.

The lengths are joined together by two main methods :—

1. The use of apparatus cases or terminal boxes and jumpering through.

2. By the use of moulded joints filled of the Gloester type.

The second method is the more modern and their use is spreading. It is generally not considered that there is any necessity at these intermediate points to provide testing facilities, particularly in view of the comparative shortness of the standard lengths ordered.

22.224. *What are the most modern means for making terminal connections?*

There does not seem to have been any change in practices for terminating wires over a long period of years, and in general nut and screw type terminal posts are used universally. Where the conductors are solid, the conductor itself is made into an « eye » to go over the terminal screw, whereas if they are stranded conductors an eyelet is pressed on to the conductor first.

The terminal screws themselves are mounted on porcelain or bakelite type bases sometimes fitted with sliding connecting links.

23.231. *Are separate cables used for each function or is use made of large multi-core cables for more than one purpose, i.e. for successive or simultaneous transmission?*

There is a unanimous reply from main line railways that use is made of multicore cables and the conductors are used for all purposes in most cases. The maximum number of cores in the cables used, however, varies quite considerably, the lowest being 24 and the highest 61.

The underground railways of London Transport Executive are the only concern using separate cables for each function.

23.232. *Do you use the cable cores for more than one purpose, i.e. for successive or simulaneous transmission?*

Modern methods of using various frequencies of carrier current for the transmission of information and methods of using polarity and time coded currents makes it possible to use conductor wires to a greater extent than was the case some years ago. The cost of the sending and receiving apparatus required for this purpose has in many cases been high and consequently its use becomes uneconomical unless there is a considerable saving to be made in its use. One of the possible savings is, of course, in the number of cable conductors required.

From the information given it appears that the use of conductor wires for multiple purposes is generally restricted to Centralised Traffic Control areas and possible a few remotely controlled interlockings. In these systems use is made of all the methods mentioned in the previous paragraph for the purpose of transmitting the controls from the central control office to the wayside station and also for the return transmission of indications. Both simultaneous or successive transmission techniques are made use of in these systems.

The use of wires in this way for ordinary straight forward circuit work does not have any application beyond the use of point machine control wires for superimposed detection.

3. Signal boxes.

311. *What system of control and supervision do you use in modern signal boxes (levers, handles, push-buttons, etc., electro-mechanical, all-relay)? Please give a short description.*

The general practice on most railways is now to adopt all relay interlockings of the route setting type for large interlockings and it is also the practice in the majority of

cases to mount the push-buttons on the track diagram. Only in one or two cases is the track diagram mounted separately from the switches or push-buttons which in turn are on a console.

Most railways have adopted the « N X » or Entrance-Exit principle for the more modern route relay interlockings. The operation is sometimes by a turn-switch at the entrance end of a route and a push-button is situated at the exit end; other forms have two push-buttons for this purpose.

In the latest British Railways type the operation is by two push-buttons, the exits button of one route also being used as the entrance button to the next or adjacent route. Route cancellation is by pulling the entrance button.

All the above types of signalling control panel use switches and indications, etc., made for the purpose, but in Sweden and Norway the route is set up by the use of a three position key of the standard telephone type, the key being turned to the left or right in accordance with the direction of movement required.

The various methods of working panels have, of course, grown up from original proprietary designs modified to suit local requirements and the requirements of the users. Consequently there are a great number of varieties of control panel in existence. Each of these varieties necessitates a considerable variation in the circuiting arrangements and consequently results in circuit designers both on the railways and in signal manufacturers offices having a more complex job than would seem necessary. It was with simplification of this in mind that the new British Railways method has been developed and also to provide a standardised method of operation. It is noteworthy that some other countries have also achieved a standard panel, but so far they are in the minority.

31.312. *Is this system the same in all circumstances (big stations, junction posts in the field, etc.)?*

The use of control panels at all stations is not the general rule in all countries, but in some the same principles of control are adopted at both large and small interlockings. This particularly applies to the U.S.A., Sweden, Norway, Finland, Rhodesia, Egypt and South Africa and does, of course, enable a greater degree of standardisation.

Several other countries use the N X principles at large stations, but individual switch operation at small wayside stations. In Japan the N X system is adopted for large interlockings, but a route lever system is used in the smaller stations.

As a matter of reducing first cost of installations a few countries retain mechanical interlockings at stations remote from the main interlockings, but work the main line signals from the main signal box and use electrical releases for the points local to the remote station. Some stations of British Railways employ the method, especially where the majority of these remote points are in a shunting yard adjacent to the main running lines. It has the advantages of cheapening the first cost and enabling the shunting at such local places to be done more expeditiously.

The so-called « hybrid » type of signal box control, that is, to work as many points and dwarf shunting signals as possible by mechanical lever frame interlocked in the same signal box with a push button panel for working remote points and all colour light running signals, is apparently not generally favoured, although it is used with considerable success on some parts of British Railways. This system is generally cheaper at first cost than full power operation, but needs maintenance by men skilled in both power and mechanical signalling equipment. On British Railways, men with these skills are generally available or can be easily trained.

31.313. *What advantages are obtained when substituting this system for the older system?*

It is the unanimous opinion of all users of the route relay interlocking panel me-

thod of controlling railway traffic that many advantages have been obtained. These advantages accrue from both the operating and engineering features of the system and are listed below :—

1. Operation is faster and more efficient.

2. Greater security is provided by the protective devices built into the system.

3. One operator can control a much larger area and consequently there can be personnel savings.

4. Greater centralisation of control can be easily attained giving a better supervision of the traffic and capacity for handling traffic is increased.

5. Traffic delays are minimised.

6. With the centralisation of signal boxes it becomes easy to integrate C.T.C. and automatic block working with the interlocking panel, again leading to higher efficiency in operation.

7. The staff can be given better conditions of work.

8. Failures of equipment are less.

9. The maintenance costs are reduced.

A number of countries are considering further developments in the field of central control with a view to reducing still further the number of staff required and to eliminate the need for judgment of conditions of traffic flows by the operators. Much of the latter work is still in the early development stages.

32.321. *How far have you gone in standardizing the elements used? Are the elements of universal use or are the control and supervising devices especially made for each installation?*

Where possible it is obviously a great advantage for both storage and purchasing of the individual pieces of equipment if a reasonable amount of standardisation can be achieved. It is always difficult to determine whether or when sufficient progress has been made in development to deviate from a standard already adopted. Purchasing policies of the various administrations which call for tenders from all suppliers of equipment also affects the degree of standardisation which can be achieved. If there is no home based industry supplying the equipment it is again more difficult to achieve standardisation.

From the replies received from the various administrations it is apparent that those countries with a home based industry have been able to obtain the greatest proportion of standardisation. For example, the U.S.A. report that the major component parts of a signalling installation (signal box equipment and some of the equipment used on the track side) are standardised and universally used; such deviations as are made from standards are those of special application to an individual installation.

Norway and Sweden have standards applied to all equipment except the signal box track diagrams which are purpose made for each station; a similar state exists in Japan.

The railways of the U.S.S.R. have the standardisation work constantly under review, both from the point of view of reducing the number of units doing the same work and with a view to bringing them up to date in the light of modern techniques and experience. They are also aiming at standardising layouts and installation of signalling so as to get the benefit of cheaper and quicker installation with a reduction in technical effort.

Other systems have achieved a certain amount of standardisation of a number of the various elementary parts; for example, relays, lamps and push-buttons or keys. They have also in certain instances proposals for extending the number of their standards.

In Great Britain mention has already been made of the latest form of panel; most of the elements of it will be standardised. Up to date most relays and other items have been specified to British Standard Institution standards. While these give the maximum sizes, performance figures and contact equipments, for example, of many relays which are used, there is no range of specifications for plug-in relays. In any case

the terminal arrangements of relays made to these specifications did not allow for interchangeability between the products of all manufacturers. A set of new specifications is almost ready for a complete new range of plug-in relays of a miniature type which will include the interchangeability feature. It is expected that the relay costs will also be considerably reduced by their adoption.

32.322.1. *Did the standardising of some elements, e.g. relays, create considerable savings in the purchase of materials?*

A number of administrations have not been able to answer this question as they had complete standardisation from the start of the newer installations. It is also interesting that some state that no saving has been made. but no reason for this has been given.

In the U.S.A. where A.A.R. standards have been in existence for many years it is reported that the savings realised are intangible.

The Japanese railways have not quantified the savings they have made, but it is stated that the cost of the elements has been reduced because of the following :—

1. Manufacturing processes allow flow-production methods.

2. Interchangeability of equipment is now possible.

3. The components of each unit are reduced in number.

4. Savings in materials has become possible.

In India, however, standardisation is claimed to have saved about 20 % to 30 % of the cost of some materials due to :—

1. All railways placing orders for similar equipment.

2. Larger orders being placed on each manufacturer enabling workshop processes to be improved.

3. Owing to the possibility of larger orders more manufacturers have come into the field and therefore competition is greater.

32.322.2. *Did the standardising of some elements, e.g. relays, create considerable savings for maintenance and purchase of spare parts?*

The experience of all concerned who have standardised these elements recently is not yet long enough to provide an answer to this question. Again, with the countries who have had standards for many years, the savings obtained are intangible or difficult to appreciate in terms of money. However, the negative approach can be made to this problem and it would be obvious that by giving up standards more difficulties would be encountered in maintenance and thus costs would tend to rise.

New Zealand, and Great Britain agree that savings in maintenance and purchase of spare parts are made, but do not quantify them at present.

Both India and Pakistan have been able to reduce stocks by standardisation and Japan reports that savings in maintenance are made and the efficiency of repair shops has increased.

32.322.3. *Did the standardising of some elements, e.g. relays, create considerable savings for maintenance personnel?*

Savings in maintenance personnel are claimed by U.S.A. railways as a result of standardisation. It can be expected that as there is not so much difficulty in replacing defective apparatus or parts then some saving of personnel should be capable of being effected, one set of standard performances only having to be learned by the maintenance or repair staff. Australia reports that some savings will be made in the future as the amount of equipment of this kind spreads in use, while New Zealand railways also claim to have made some reasonable savings.

It is felt in Japan also, that there have been some savings in maintenance person-

nel as inspection and adjustment becomes easier. The Pakistan railways consider it to be an advantage to have standard equipment, as it enables the staff to be sent from one station to another for maintenance purposes.

On the other hand a number of other countries find that athough savings may be possible in time, it is too early to judge the effectiveness of the steps which have been taken in this direction.

32.323. *Do you use individual relays or sets of relays in interchangeable units? What advantages are claimed for one system or the other?*

It has been normal telephone and telegraph practice for some years to assemble certain parts of the Exchange equipment into standard sets, all of exactly the same pattern both as regards wiring and apparatus in them. These sets are of plug-in variety and are readily changeable in the event of failure or maintenance being required. The racks carrying these sets of equipment carry the interwiring between them. Thus when a set of equipment is removed the permanent rack wiring is undisturbed.

In railway signalling, however, with some designs of relays this is not practicable owing to the large size of the individual relays; any sets which might be made would be too heavy to handle. Nevertheless, there have been developments since the second World War in circuit designs using what are known as « geographical circuitry », or « Spurplan Technik » as the German system is called. In these systems standardised sets of relays for points, signals, shunting signals, etc., are connected together in geographical sequence according to the requirements of the particular layout of the points and signals. These sets are of plug-in type and are only feasible because miniature type relays are used.

Where the circuitry is of a type as used in the control and indication circuits of C.T.C. for example, the relay set has been used for a considerable number of years. More recently relay sets have been used for a variety of other purposes where the circuits are non-vital.

At the present time the majority of the railways use individual relays in most vital circuits and sets of relays are used in non-vital circuits. Great Britain and Sweden are developing the relay set technique for use in vital circuitry.

On the other hand the advantages claimed for the relay sets are :—

1. Ease of design or circuits; it is not necessary to draw out all details.

2. Saving in engineering staff time.

3. Equipment being made in standard sets can be manufactured while circuits are being designed.

4. Ease of installation.

5. All wiring can be carried out in the factory.

6. There is an economy in space.

7. Faults in signalling installations are easily and quickly rectified simply by changing the faulty set, which is then dealt with in the factory.

It is to be appreciated, however, that the older large relays are completely unsuitable for this purpose.

33. *What other measures or devices do you use for facilitating the tasks of the personnel, for extending their area of control or cutting their number?*

Having concentrated the control of points and signals into a central signal box, opportunities are presented for further development of automation. A variety of devices are at present in use, all of which may be called aids to the signalman and while they enable the area of control to be extended somewhat it is not easy to determine the savings in personnel which are effected. There are a few applications of automatic working of points and associated signals in use both on lines for dense passenger train working and in marshalling yards. In the latter case the control may be stored and released by « memory » dev-

ices of various kinds, for example the use of progression relays or punched tape.

On passenger lines British Railways have for many years had simple crossovers and associated signals controlled automatically, this control being through track circuits successively occupied and released. This application is, of course, for use when the movements required follow a set pattern which is unvaried. One of the most notable applications of automatic working is that in use on the London Transport Executive Underground Railways and a description of the application is given in Robert Dell's Paper « Automatic Junction Working and Route Setting by Programme » read on 23rd October 1958 before the Institution of Railway Signal Engineers in London and subsequently published in the Proceedings of the Institution of Railway Signal Engineers. On this system quite extensive sections of London's underground railways are automatically worked.

Other means of operating simple junctions are provided by the Identra system as used in the U.S.A. by which a tuned coil is mounted on the train itself; when this passes a receiver mounted on the wayside a junction some distance ahead is set to the required position.

Where train describers are used they are also sometimes connected into the signalling scheme for controlling route setting.

In Finland use has been made of route storage equipment so that crossing loops on single lines within the remote control area are operated automatically by the trains themselves.

Many railways, particularly in the U.S.A. and Great Britain, arrange for facilities to be built into the control system for converting controlled signals to automatic working when this can be done. At many periods, for example, morning and evening peak commuter traffic, the movements of trains are straight along the running lines and no crossing movements are required. It is advantageous then to use the automatic facility which is easily made available. These facilities also enable a signal box to be closed at periods of light traffic.

On those railways where traffic is dense some form of train description equipment is called for and this is sometimes arranged to provide an indication of the train description at each main and loop line signal. The signalman is thus given complete information of the train and its position on the track diagram.

Where traffic is comparatively light telephones are provided at certain main signals to enable loco drivers and signalmen to get into contact with one another; in the U.S.A. this is sometimes done by means of radio equipment between the signal box and train.

In Great Britain there are separate telephones provided to the signal box at all automatic signals and certain home and starting signals a long way from the signal box to enable the signalman to give instructions to drivers in the event of signal failures. The « Stop and Proceed » rule was abandoned in that country many years ago owing to several accidents which occurred.

It is the general practice to determine the economic justification for the adoption of any of these devices not only in terms of money, but by the extent to which they will be used and their effects on traffic working.

34.341. *Do you use remote control with satellite posts either electrical or mechanical? Please give a short description and show the advantages and the economic limits.*

There are often junctions or small interlockings several miles away from a main centre which some countries are finding difficult to staff. It therefore becomes a problem to connect them to the main centre and work them economically. Assuming that the layout has been reduced to the smallest possible number of signals and points, there then remains a choice of method of working :—

1. To connect all points and signals to the main centre working them electrically with a choice of :—

a) individual wires to the functions, or

b) adopting some form of carrier current equipment to convey the necessary controls and indicators.

2. To connect such points and signals as are necessary for through running movements to the main centre by either of the means given in 1 *a*) or 1 *b*) above, and leave the remainder to be worked locally by manual means, transmitting the necessary controls by either of the above mentioned means.

3. To allow the train crew to work the points and shunting signals locally by manual means as required and work the main signals from the main centre, in which case the necessary interlocking and controls between running signals must be ensured by the means given in 1 *a*) or 1 *b*) above.

Similar principles for controlling remote interlocking have been found necessary in a number of cases when the remote interlocking or junction is of new construction, in which case even if the staff can be found to work the interlocking it is necessary to provide adequate housing and amenities, etc., for the staff and their families.

No one method of carrying out such work has been adopted by any railway and most of them use one form of control or another, depending on the circumstances arising in each cases. The economic advantages of one method as compared with the others is generally assessed before reaching the final decision.

Where C.T.C. has been introduced all the above methods have been adopted for dealing with stations away from the main control centre. In C.T.C. areas the wayside stations are invariably satellite interlockings operated by coding over line wires, both the controls required and indications to be received. Some railways use a minimum of indications which may only show a change in point position or signal aspect. Sometimes equipment is provided to keep the point, signal and track circuit conditions under constant supervision, but this is a matter for local requirement of each concern.

The U.S.S.R. railways report the substitution of C.T.C. for electric train staff methods and manual control has increased the line capacity by 25 % to 30 %, ensuring an average overall speed of 120 km per hour and a staff saving of about 50 men per 100 km of railway.

34.342.1. *Does remote control make it possible to reduce the number of tracks?*

It is generally agreed that it is possible by signalling which may be controlled by both C.T.C. and remote control within a large area to effect track saving. For example, there are many cases of double tracks being converted to single tracks and of four tracks to two; in addition, there are many cases where the provision of C.T.C. with modern signalling has enabled the traffic to be carried on single tracks and obviated the necessity for doubling the line.

Cases are also reported of the savings in other structures, as in Pakistan, where the introduction of remote control has avoided the doubling of two major bridges.

34.342.2. *Does remote control make it possible to increase the capacity of a single track?*

Many railways throughout the world have had their single lines fully signalled with semaphore signals and mechanically operated points at the crossing loops, the sections of single line between loops being worked by electric train staff, tablet or token systems. The time taken to carry out the block instructions and change the token can often be very appreciable and also the fact that there is no overall supervision of the trains running on the single line can lead to delays. All organisations are agreed that the introduction of remote control systems in place of the token system does in fact enable the track capacity to be increased. Naturally, where a train order system is in operation a very much greater increase in capacity can be achieved.

34.342.3. *Does remote control make it possible to use two way working in multiple track areas?*

Many railways have traffic conditions arising at certain times of the day or periods of the year when there is a preponderant flow of traffic in one direction: hence if the line is a double track one with one line for each direction there can arise the position that one track is overloaded while the other may be out of use. It is possible to devise means of working each line of a double track by a signal box at each end of the section, but without doubt, and this is the opinion generally expressed, two-way working for running trains on double tracks is only a practicable proposition with remote control. The presentation of information of traffic over the whole section of railway is of great value for the operation of the traffic in the most efficient way.

34.342.4. *Does remote control make it possible to enable two trains to pass or overtake without stops?*

This question is one in which it is very necessary to determine whether the operating advantages of being able to do this is really necessary and worth the additional expense. Whereas it is possible under two-way working on double track to carry out manoeuvres such as this, on single tracks the crossing loops must be long enough to allow this to be done, making in effect a section of double line. Not only is there an increase in signalling costs, but also a substantial increase in permanent way.

In order not to stop trains at a crossing loop, it is necessary to have a complete picture of the train movements over at least three crossing loops and the intervening line, hence it is agreed that it is only by the introduction of remote control that it becomes possible to ensure such traffic movements.

34.343. *Can you calculate the savings of these possibilities?*

In the U.S.A. under the auspices of the A.A.R. a number of Committees are given the task of keeping under review the economies of each particular type of installation. Consequently there is in that country a well organised system of assessing the savings and potentialities of all types and classes of equipment and devices for the safe and efficient movement of traffic. The American railways'answer to this question is thus in the affirmative.

In Great Britain it is felt that this might be done in a few specific and limited cases, while most other countries have not attempted to establish reliable figures for this purpose.

35.351. *Do you use automatic train control in main tracks and does it lead to savings in personnel?*

Unfortunately this question has been interpreted in two different ways inasmuch as the term « Automatic Train Control » has in many cases been used in the older sense for equipment now known as « Automatic Warning System of Train Control » in Great Britain, Cab Warning in Japan and Cab Signalling in U.S.A. The intention of the question probably becomes clearer if instead of « Automatic Train Control » is written « Control of Trains by Automatic Means ».

The use of equipment in the first sense of the question is restricted to U.S.A., Great Britain and Japan and in no case is it claimed that savings in personnel have been effected, indeed the opposite is the effect in so far as there is more equipment to maintain.

So far as the second interpretation is concerned this question is under study in U.S.A., U.S.S.R. and Great Britain, but it is too early to assess the position.

35.352. *Have you remote control for shunting engines and does it lead to savings in personnel?*

In modern marshalling yards many countries have now installed radio links between the main control cabin and the shunting engines. By its use a better control is established over the movements of these engines and it has very distinct advantages over the

older loud speaker installations. Where it is used some savings in shunting power have been made and in the end personnel have been saved. Generally speaking the radio system really supplements the loud-speaker, which is used nowadays for communicating more with the yard staff. Radio equipment is very much cheaper than the loud speaker system.

The use of radio has naturally brought about the possibility of shunting by means of locomotives without crews controlled from the main control cabin. Cases of this method of control are reported from U.S.A. and Great Britain.

36.361. *What is the normal electricity supply used to signal boxes?*

The value of the voltage used for any purpose can, of course, have a considerable bearing on both the economies and physical sizes of both equipment and cables. With the passage of time the easier access to commercial supplies of electricity from major electric power distribution systems has led to the possibility of reconsidering the voltages which can be used for signalling purposes. It is no longer a question of designing to suit an electric supply which depends wholly or partially upon either secondary or primary batteries, and thus upon an expensive source of supply. It is to be expected, however, that it will be a considerable number of years before the primary or secondary cell can be dispensed with entirely in all countries.

It is generally not possible to obtain a main electricity supply which can be said to be 100 % reliable and therefore various means are used to overcome a failure of supply should it occur. Alternative supplies are usually arranged and may take the following forms :—

1. Second supply from another primary source.

2. Standby Diesel generating plant.

3. Standby battery with or without motor-alternator sets.

In many cases a combination of these may also be used.

36.362. *What are the auxiliary sources of electricity?*

The question of whether or not to provide an auxiliary source of supply is not always an easy one to answer as often the duplicate equipment could be unused for many years. However, its cost has to be balanced against the disruption to traffic which can occur in the event of a primary power failure and each case is again taken on its merits.

The general rule seems to be that where it is possible to obtain two supplies from the commercial primary network the chances of a complete power outage are very remote under present day conditions. The primary commercial network usually is capable of being maintained alive under all circumstances.

Two supplies from a secondary commercial network would not be anything like so reliable and as the category of network reduces so the reliability decreases.

It is the practice in a number of countries in these days to attempt to obtain the two independent supplies through independent commercial substations connected to the primary network, but where this is not possible one such supply is taken and a Diesel generating set is installed as a standby. The Diesel set is equipped with automatic starting gear and changeover contactors; these sets are usually also fitted with push button starting gear for testing purposes and sometimes are used for a short period each weekend to take over the power supply. This ensures that the sets are kept in good working order and enables maintenance to be carried out on the normal power supply equipment.

Where A.C. electric traction is on use as in Sweden, Norway, Japan and Great Britain the normal supply is taken direct from the catenary. The standby supply may then be from the local commercial network or if this is not possible a standby Diesel generating set is installed.

In a few cases where C.T.C. has been adopted and the railway runs through comparatively undeveloped country, no local

supplies are available at the various stations. It is then necessary no install a system which is basically D.C. operated so that battery supplies can be used normally. These batteries may be of the alkaline or acid type and are usually charged by a small diesel generating plant installed locally and switched on and off by means of controls from the main C.T.C. panel.

The outputs of the generators in all these cases depend on local circumstances, but the voltage is normally that of the local signalling power distribution network.

36.363.1. *What are the characteristics of electricity supply used for moving points?*

The operating voltages for point machines seem to vary quite considerably in the different countries as also does the use of either A.C. or D.C. motors in these machines. The choice is made from the values shown in Table 1. (See overleaf.)

The lower D.C. voltages of from 20 to 36 are usually used for slow speed motors working at remote and comparatively simple interlockings such as crossing loops in

TABLE 1. — **Point machine operating voltage.**

D.C.	A.C. 50 or 60 c.p.s.	
	Single phase	*Three phase*
20 V	—	—
24 V	—	—
30 V	—	—
36 V	—	—
110 V	110 V	—
120 V	120 V	—
130 V	—	—
220 V	220 V	—
—	—	380

C.T.C. areas or running loop exits. They are generally fed from trickle charged secondary cells, but sometimes are supplied direct from a metal rectifier according to the standby supply arrangements.

The higher voltages both D.C. and A.C. are used for large concentrations of point machines as found in the larger interlocking. The D.C. point motors are then fed from trickle charged secondary batteries, the latter being admirably suited for taking peak loads when a number of routes are being set up.

In some countries, 3 phase A.C. supplies are not always available and consequently the smaller and simpler machine with the higher voltage is not possible to use and so cost of supply points for power, together with difficulties in the standby arrangements, have reacted against the adoption of such machines, although they are much cheaper than other forms.

36.363.2. *What are the characteristics of electricity supply used for moving or lighting signals?*

For lighting signals the determining factor for choice is the fact that the lamp filament has to be concentrated in a very short length and therefore the tendency all over the world is towards one standard value. Table 2 shows the figures chosen :—

TABLE 2. — **Operating and lamps voltages for colour light signals.**

Operating voltage		*Lighting voltage*	
D.C.	A.C.	D.C.	A.C.
10	—	—	10
12	—	12	12
24	—	—	
—	—	—	30
—	110	—	110

The operating voltages shown in the table are those used for operating the so-called « searchlight » signals. Most signal lamps are working at 10-12 V A.C. or D.C. but 110 V commercial lamps are used in Great Britain for position light shunting signals.

The operating currents are transmitted directly from the control centre, either a signal box or a field station in the case of C.T.C. installations. The signal lamps are usually supplied from an A.C. distribution system, often 110 V or 220 V, through transformers or rectifier sets.

36.363.3. *What are the characteristics of electricity supply used for track circuits?*

The supply for track circuit purposes does not seem to have varied greatly over the years, except in cases where high voltage commercial frequency electric traction has been introduced. The track circuits are normally fed by tapping the signalling supply distribution mains with a step down transformer or rectifying set for each track circuit feed end. The output side of the transformer varies in voltage according to the type of adjustment required. As all these systems are not new, it is not intended to list them.

For the newer electrified lines using high voltage 50 c.p.s. A.C. for traction purposes some variations have been adopted by various countries and are shown in Table 3 :—

TABLE 3. — **Track circuit feeds in high voltage 50 c.p.s. A.C. traction areas.**

Country	*Type of track circuit feed or supply*
Japan	1. D.C. (Track relays must be immunised). 2. Two-phase, 4 wire, 110 V at 83 1/3 c.p.s. or 100 c.p.s. 3. Audio frequency between 2 000 and 4 000 c.p.s. pulsed by 1/2 of industrial frequency. 4. For sections between stations audio frequency at 720, 960 and 1 200 c.p.s. modulated by 20 or 35 c.p.s.
Great Britain . .	1. D.C. (Track relays must be immunised). 2. Single phase 75 c.p.s. A.C. from static converter with 50 c.p.s. input. 3. Two-phase 83 1/3 A.C. and wire system.

For the lower frequency traction systems used in Sweden and Norway similar arrangements are used to the two-phase systems mentioned in Table 3, but Sweden uses 75 c.p.s. and Norway 100 c.p.s.

It is now the practice in Great Britain to use the D.C. immunised track circuit in the high voltage 50 c.p.s. A.C. traction areas, as it has proved to be very reliable and cheaper than other forms so far adopted. The two A.C. track circuit feeds were only used for areas converted from D.C. traction to the commercial frequency A.C. system and formed a convenient means of converting existing A.C. track circuits.

It is apparent that there has not been much development or increase in use of the low frequency coded type of track circuit, which developed from the cab signalling frequencies and was advocated as a means of dispensing with line wires.

36.363.4. *What are the characteristics of electricity supply used for supervision?*

For supervising circuits there is again a considerable variation in type and voltage of current used and it would seem that like many other similar supplies it is the result

of development by individual concerns along similar but unco-ordinated paths. Table 4 gives a list of such voltages.

TABLE 4. — **Voltages and type of current used for supervising purposes.**

D.C. voltage	A.C. voltage (50 or 60 c.p.s.)
10	10
12	12
24	24
32	—
36	—
50	—
60	—
—	110
—	120

No preference is expressed for any particular voltage for this purpose by any of the users.

36.363.5. *What are the characteristics of electricity supply used for interlocking?*

Interlocking circuits generally require considerable lengths of internal conductors and comprise a large number of relay or other contacts in series and finish in operating a relay or electrically operated lock of some kind. Past practices have grown up round the characteristics of these relays and electric locks, but the development of new materials and techniques in the manufacture of this equipment may lead to changes in the value of the supplies adopted. Table 5 gives a list of both A.C. and D.C. supplies used at the present time :—

TABLE 5. — **Voltages of supplies for interlocking purposes.**

D.C. voltage	A.C. voltage (50 or 60 c.p.s.)
10	10
12	12
24	—
36	—
50	—
60	—
—	110

In Great Britain and some other countries newer systems are being designed to use 50 V D.C. for this purpose, it being obtained from rectifier sets.

36.363.6. *What are the characteristics of electricity supply used for remote control?*

The voltage and type of current for remote control purposes varies very much according to whether the remote control is for extensive C.T.C. purposes or just to work a junction or small interlocking a fair distance from the central control point. The majority of supplies for this purpose have to be chosen from one of the D.C. voltages, but some installations do exist which use A.C. Table 6 summarises the variations to be found :—

No preferences have been expressed for any of these voltages and they are presumably the result of manufacturing concerns developing rival systems.

37.371. *How is the internal wiring done in a signal box? etc.*

In the last decade very considerable advances have been made in the material

TABLE 6. — **Voltages and type of current used for remote control purposes.**

D.C. voltage	A.C. voltage (50 c.p.s. or 60 c.p.s.)
10	10
12	12
24	—
36	—
48	—
60	—
80	—
100	—
110	110
130	—
190	190
220	—
—	240

and methods used for the internal wiring of signal boxes. To a certain extent this has been brought about by the design and more general use of the plug-in or detachable relay mechanism. The fact that it is not now necessary to disconnect wires from relay terminals means that there is less chance of error in the changing of relays; modern designs of relays also do not require the same size of conductor to carry the operating current, while the development of really fireproof insulating material has led to a smaller overall diameter cable. The greater confidence which engineers have in modern insulating materials has also led to the adoption of thinner insulations, for example, at one time a 660 V grade insulation was used for circuits with an operating voltage of 12 V; nowadays, with an operating voltage of 50 V a 250 V grade is adopted.

As far as it is practicable, a number of organisations have adopted production methods in the wiring of lineside apparatus cases or even of complete huts. This may be carried out in a manufacturers' works or very often in a central depot belonging to the railway. The wiring may be attached to relay racks or it might be made up as a harness and taken to the site of the work for connecting up, the harness being made on a dummy relay rack or on a pin-board. Consideration of weight and handling methods determine whether it is wortwhile prefabricating a whole case or in particular a hut.

For signal boxes of the smaller sizes, the same principles can be adopted for the relay racks themselves, but for the large interlockings where a large number of racks are needed, the general rule seems to be that the racks are standard in size and the wiring of each rack may be prefabricated; wiring between racks is carried out in situ.

By far, the greater number of organisations now use one of the modern fire-resisting plastics, such as P.V.C., neoprane or P.C.P. for the insulating material. Some of these materials have the advantage of being easily coloured and have a colour code for circuits which can be used if necessary. The terminal-to-terminal wiring of a relay rack may be done either with a small gauge solid conductor or a stranded conductor. Between racks the wiring may be carried out by the use of the same kind of single core cable or very often with a multicore cable using the same plastic insulation and sheathed with a similar material.

The wires themselves may be run in troughing, or in « open trees » supported by hooks or rings, while one or two organisations are using the former method the majority favour the latter, but with modern small diameter cable it is no longer necessary to lace the wires together as was often done formerly. While lacing made a very neat job it was altogether too expensive and the cost cannot be justified. The smaller wires are run tidily and bound together with a plastic tape or some such material at

intervals to hold them. The hook or ring is attached to the relay rack and is used to carry the wiring.

The wiring or cabling between racks is now carried in open metallic troughing or on horizontal ladders.

The use of modern plug-in type relays has also led to the standardisation of the sizes of relay rack to be used. It is no longer the practice for large racks to be built up in a signal box. Today a relay rack can be prefabricated in standard sizes. The majority of railways still adopt a welded rolled steel section frame for this purpose, but it is reported that some cheapening of this work may be made by using « Dexion » or a similar slotted steel strip.

37.372. *What methods are now adopted for terminating wires?*

For many years wires were terminated on a nut and screw type terminal and soldering was not favoured in many places as a satisfactory means of making off a wire. Present day designs of relays with plug-in features generally necessitate either soldered or crimped joints and these have proved satisfactory wherever adopted. Although it is necessary to keep to screwed type connections in some instances, it is now the more general practice to use crimping where possible and soldered joints in other cases where possible. Generally speaking these joints are considerably cheaper than the type formerly used.

37.373. *Could all this lead to standardisation of whole installations of signal boxes or relay houses?*

There would still seem to be a divergence of opinion as to the possibility of standardising a whole installation. The advantages in remote installations of being able to purchase and transport a « ready to fit » installation are fairly self-evident and it appears to be the ideal to aim at.

A number of countries hold this view and in particular refer to the smaller signal boxes and relay houses and this practice has already been adopted where possible. Other organisations point out that in the larger installations there is a very considerable variation of the layout of tracks and point connections and that the elementary parts of the layouts would have to be standardised before attempting this work.

Again others consider this is an ideal, but nevertheless an ideal which is not too impracticable of achievement.

38. *What use has been made of electronic units for purposes other than transmission of speech? Please describe the types of equipment which have been converted.*

Whereas relay techniques have been used for many years with very great success and extreme reliability for signalling and other associated forms of engineering, a large number of new and interesting devices have become everyday features of many forms of equipment for other fields of engineering. Although it is fashionable to follow some of the modern trends, there is no doubt that new possibilities are opening up which may lead to newer conceptions of railway signalling and also to cheaper equipment.

For a long time the thermionic valve dominated the field of engineering now called electronics, but it would be true to say that for most applications in railway signal engineering anything of the nature of an evacuated glass tube with delicately suspended electrodes and filaments is not a very practical device. Consequently applications of electronics to railway signalling work were not favoured, firstly, on the ground of unreliability in service; secondly, doubts as to whether wrongside failures would not become more frequent; and thirdly, on the question of first costs and maintenance costs.

The advent of transistors, ferrites, newer designs of thermionic equipment, etc., have altered this picture very considerably and there is now the possibility of using more and more of this type of equipment in railway signalling, as most of the disadvantages of the older thermionic devices are not to

be found in them. They have, of course, other disadvantages inherent in their own peculiarities.

For a long time the only application of electronics to railway signalling has been in the use of a « carrier » to extend the length of railway line which could be controlled by C.T.C.; a logical development from telephone and telegraph engineering. This type of C.T.C. apparatus is found in most countries that have adopted C.T.C. A later development of this type of control equipment in which all the elements for coding and transmission are of the « static » and « transistorised » type has been installed in Great Britain for remote control purposes and in South Africa and New Zealand for C.T.C. Railways in the U.S.A. have used similar devices for transmitting and receiving indication codes in C.T.C. areas. It is claimed that by using printed circuit techniques there is a reduction in cost, without loss of reliability and ease of maintenance since the printed cards are easily changed in the event of a failure. The failure can be ascertained in the workshop and rectified quite simply.

Since World War II much work has been done in Europe on designs of track circuits using audio frequency short duration peaks of voltage, sometimes up to 120 V, to overcome high resistance contact between rail surface and wheel tyre. Generally speaking although these track circuits are very successful they are more expensive that the conventional type of track circuit and consequently it is unlikely that they will supercede the latter entirely for a long time. In Great Britain, however, a number of this type of track circuits have been installed for the purpose of providing a reliable type of circuit where rail surface are bad. These track circuits have the following characteristics.

A thyratron tube is used to produce very short pulses of energy at a potential of about 1 350 V. These are fed to a track transformer (which may also serve as an impedance bond) where they are stepped down and fed to the rails at approximately 135 V. The length of the track circuit is limited by attenuation to about 1 000 yards at which distance the rail potential will have dropped to about 60 V.

The high voltage will break down most forms of rail film but, because of the very short duration of the pulses, the total power consumption is not excessive (150 va.).

On the other hand the Japanese National Railways are extending the use of audio frequency track circuits in the A.C. electrified areas. These track circuits are also used for cab signalling purposes on the Japanese National Railways. The characteristics are given below :—

1. Two frequencies, used on alternate track circuits, of 720 c.p.s. and 960 c.p.s. are used for carrier purposes. These are modulated invariably by a frequency of 20 c.p.s.

2. On an average the minimum input voltage of the receiver is 0.25 V.

3. The equipment is designed to work on a track circuit up to 2.5 km in length with a ballast resistance variation between 2 and 10 ohms/km.

4. It is claimed that the train shunt sensitivity of these track circuits is higher than the conventional type.

In Great Britain experiments have been in hand for many months with the French Aster Co. type of track circuit for eliminating the use of insulated rail joints. These have been very successfull and the use of this type of track circuit will be extended widely as they enable long welded rails to be used, the expansion joints of the latter being placed independently of the positions of signals. On the D.C. third rail and overhead systems of electric traction a very considerable saving of money is made by the elimination of impedance bonds. The characteristics of this type of track circuit are developed round the use of the impedance of a length of rail and tuning this into the circuit are as follows :—

Transistorised oscillators, operated from an 8 V D.C. source produce any of six different frequencies in the 1 600-2 600 c.p.s. range. Three alternate frequencies are used successively on one track and the other three on the second track. Each oscillator

is connected to the rails through a tuning unit which is resonant at the particular frequency used. At the far end a potential is established across a second resonant unit and this in turn is amplified and fed to an orthodox type of D.C. relay. This track circuit is limited in length to about 880 yards, but up to this limit train shunts of not less than 0.5 ohm can be obtained. Adjacent track circuits overlay each other by some 20 yards, under average ballast resistance.

signal ahead. The display of the indicating lamp does not change even after the driver acknowledges the warning.

The wayside transmitter generates a carrier frequency of 1 300 c.p.s. modulated by two low frequency codes, 20 c.p.s. and 35 c.p.s. This modulated carrier current is superimposed on the 50 or 60 c.p.s. track circuit current.

The receiving set attached to the head of the train picks up the current, amplifies it and selectively works relays according to

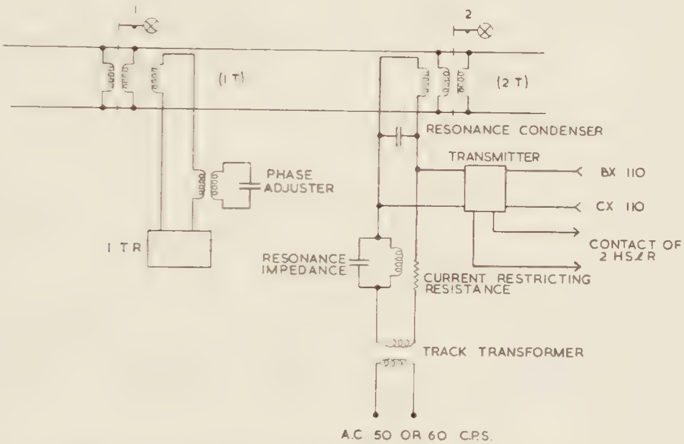

Fig. 5. — Standard connection of wayside track circuit.

For a long time electronic circuits have been used in the U.S.A. where cab signalling is in wide spread use, much of this type of equipment being in the receiver circuits on the locomotives. More recently attention has been given to units for superimposing A.C. coded cab signal energy on D.C. track circuits. A similar application of electronic circuitry is reported from the Japanese National Railways where three different systems of cab warning have been devised and are called Types A, B and C.

Type A.

Is used in automatic block sections. When the train proceeds beyond a Caution signal, the cab warning sounds and the indicating lamp repeats the aspect of the

the codes of the track side current. Selection of codes is so arranged that a 20 c.p.s. current is transmitted over the section while a Proceed signal is showing and a 35 c.p.s. current when the signal is at Caution. While the train receives 20 c.p.s. current, the indicating lamp in the cab shows a white light. When the code changes to 35 c.p.s. this light turns red and rings the alarm bell at the same time, thereby giving a warning that the signal ahead is at Stop.

If the train proceeds beyond the Stop signal and into an occupied section the code current in the track circuit is shunted by the preceding train, causing the relays in the cab equipment of the second train to drop away and to flash the red indicators in the cab warning equipment and simul-

taneously sound a buzzer alarm (fig. 5 and 6).

Type B.

This is used in urban electric railcar working where there is very heavy traffic. track circuit current which is inductively picked up by the receiver mounted on the train.

The train equipment consists of an inductor, amplifier, indicating light, acknowledgement switch, etc. (See fig. 7 and 8.)

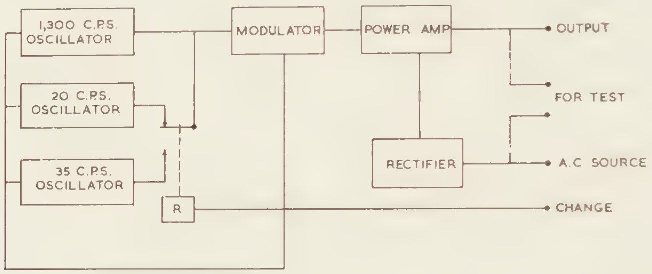

Fig. 6. — Block diagram of transmitter of type A cab warning.

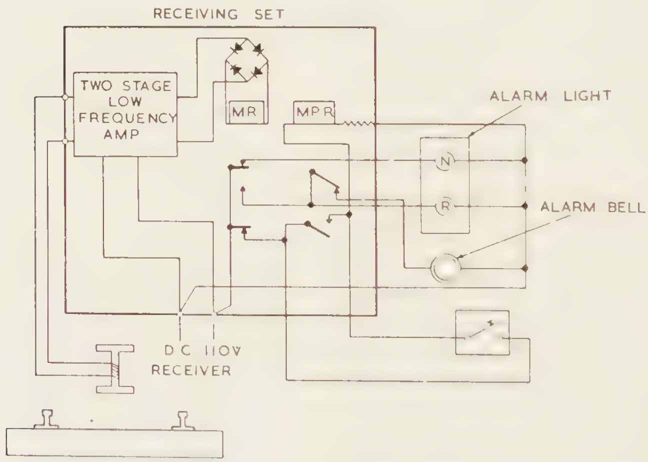

Fig. 7. — Principle of type B cab warning device on the train.

This equipment causes a bell to ring and a red lamp to light in the cab, when the train reaches a point approximately braking distance from the stop signal ahead. The driver is given an acknowledging button which has to be pushed to re-set and must take appropriate action.

The system makes use of the existing

The wayside equipment consists of an approach relay and a time element relay inserted into the track circuit of the automatic signal. The A.R. which is a kind of track relay installed at the transmitting end, is used to interrupt the track current when a train approaches. That is, it is energised together with I.T.R. while there is no train

or car on the track circuit and it is de-energised with the increased train shunt current when a train reaches the point « S » at the pre-determined distance « L » from the signal. Once A.R. is de-energised, it cannot be picked up again until the train clears the section « L ». The signal current is transmitted into the track circuit I.T. when signal 3 shows « clear » or « caution », ling relay at the distant signal) according to whether the signal shows « clear » or « caution ».

The schematic circuit diagram is shown in figure 9. The cab equipment has a coil and an oscillator which generates a frequency of 104 kilocycles. The wayside coil is connected with a condenser in parallel which tunes the coil to resonate at 130 kilo-

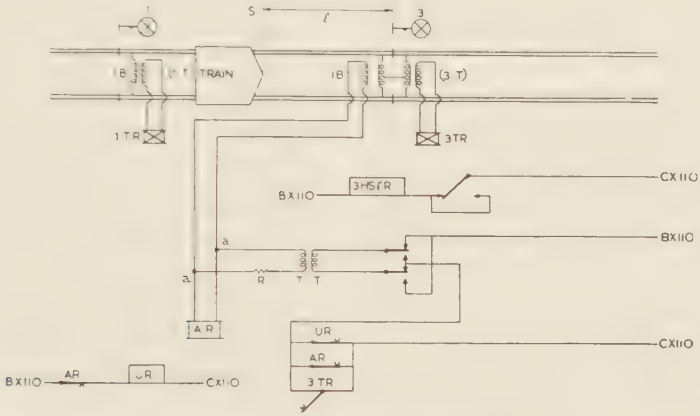

Fig. 8. — Connection of wayside device of type « B » cab warning.

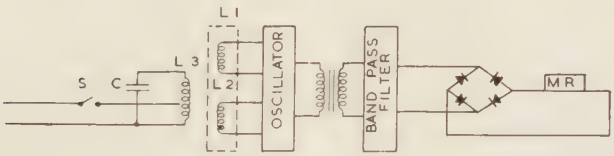

Fig. 9. — Scheme of type C cab warning device.

when either the A.R. or the U.R. (the time element relays) is energised, etc. If signal 3 shows a « stop » aspect when the A.R. is de-energised at the approach of a train, the track circuit current is cut off until the time element relay has functioned.

Type C.

This equipment is used mainly in non-automatic block sections and where there are not necessarily any track circuits. It is an inductive system depending on closing and opening a wayside coil (by the control-

cycles, a tapping being made to the coil and connected through a contact on the signal control relay. When the distant signal is at « caution » the coil is open circuited.

In the first case the oscillation frequency of the cab equipment is arranged not to alter and thus the cab relays are kept energised. When the wayside coil is open-circuited the oscillation frequency changes and the cab relays are de-energised, thereby sounding an alarm bell and lighting a red lamp in the driver's cab.

The Japanese National Railways have introduced a device for train identification. The apparatus is for increasing the track capacity by discriminating between kinds of train (electric multiple unit, passenger train or freight train) which are required to use the same road, but which require different braking distances. This device can also be applied to highway crossings protected by automatic barriers since with it, it is possible to make the operating times of the barrier equipment uniform for all kinds of train.

The working principles of the device are briefly as follows. There is a wayside equipment and a cab equipment. The wayside equipment, which is installed near the track, has an amplifier, an input coil L_1, and an output coil L_2. Both L_1 and L_2 have values and are fixed in a position so that no oscillation is caused by the feed back, i.e. when the mutual inductance is either zero or a minimum.

The cab equipment has a resonance circuit of inductance L_3 and capacity (resonance frequency F). It is installed at the lower part of the front of the train.

If L_3 moves near to wayside coils L_1 and L_2 respectively, inductive coupling is created $L_2 — L_3 — L_1$ and at that time an oscillation of frequency F starts in the wayside coils. The current thus induced is passed through a band pass filter then an output transformer to a rectifier which energises a control relay, which identifies the particular train. By using band pass filters and controlling relays to work with different frequencies, any number of varieties of trains may be identified.

The U.S.A. is the only country which is using hot box detectors and there have been some electronic units devised for operation with this device. The U.S.A. is apparently the only country which is at present actively studying the use of electronic control equipment for automatic train operation, but no information is available at the present time.

Norway reports the use of a few components such as equipment for controlling battery charging current and for remotely indicating the position of automatic highway barriers. There are, however, no comparable units of non-electronic type. Electro-mechanical timing relays have also been replaced by electronic units.

Sweden has reported that certain components have been made electronically operated and mention flashing apparatus for signals.

The so-called « overlay » track circuit is finding increasing use; these are track circuits of very short length, say of a few feet. They are operated at 10, 20 or 30 kilocycles, and are taking the place of electro-mechanical treadles or are being superimposed on other track circuits for the purpose of giving releases and for timing sections, or also for detecting positions of vehicles.

The development of electronic switching ideas for telephone exchanges and similar apparatus has lead also to the study of electronic switching for train description apparatus, but although a few minor applications have so far been used, no fully electronically switched equipment has yet been reported in use.

In Great Britain an installation comprising electronic units only is being brought into use. This will be a full scale trial of safety circuits worked by these units, with a view to proving reliability and to gain the field experience required to consider production designs with a view to testing whether the electronic method is ultimately cheaper to manufacture than all relay equipment.

In a modern mechanised marshalling yard electronic equipment has been largely adopted for the calculation and control of the braking forces required to be applied by the retarders. In Great Britain the later yards are also being equipped with electronic units in place of the progression relays for the automatic switch operation and thus most of the internal equipment in such a yard control is now of the static switching variety.

4. General questions.

41. *What steps have been taken or methods adopted, in addition to those mentioned above, to reduce the costs of :*

41.411. *Planning of projects?*

The planning and detailing of a large signalling installation is one which requires a technical effort on the part of the signal engineers staff of very great magnitude. Owing to the very specialised nature of the work, the fact that the necessary experience for such work depends on the continuing development of railway schemes and also that the knowledge and techniques required are necessarily limited to a comparatively small number of people, a study of the development of ways and means to reduce the technical effort required has become necessary.

If it were possible to standardise the layout of tracks and junctions the task of the planners and detail engineers would be much more simple. Often, however, this is not practicable but where possible attempts are made to do this. A few countries have been able to standardise the layouts to wayside stations to a very great extent, this being possible particularly where new railways are being developed. They are then able to use standardised interlocking and controls, standardised estimates and bills of quantities for such places.

The U.S.A. report that use is being made of electrified computers to supplement the engineering judgment of the planning staff, but no details have been given.

A common practice is to use prototype details for elementary parts of a track layout e.g. rail joint, insulation diagrams, standard circuit elements, etc., together with the use of pre-printed detailing sheets to the greatest possible extent.

One or two organisations recommend that instead of a planning group taking a particular signalling project from its first inception right through to its final implementation, there should be a separation of the work into a planning section and another for the elaboration of the details. Others, however, feel that this is going too far and by dividing the interest of the staff has two disadvantages :—

1. The sense of being part of a team running the project is lost and thereby a lot of the interest.

2. This division ultimately means that there can be little or no interchange of staff on projects and thereby aggravating the position when :

a) the bulk of the office work is planning; and

b) the bulk of the work is detailing.

Eventually it is also felt that for the filling of senior jobs a comprehensive and modern knowledge of both sides of the work is essential and such a proposal can only hinder the development of fully experienced engineers.

The standardisation of the controls and indications required at each individual pair of points and associated signals can, however, lead to a more logical development of aids to quicker detailing. Two or three systems of the so-called Geographical Circuitry techniques have been developed in Europe to suit the conditions met there. In these systems there are a few (six or seven) standard blocks or packages of relays which can be used in any layout. These packages which represent say a running signal, a facing point, a shunt signal, etc., are then connected together in accordance with their sequence on the geographical plan of the signalled track layout. It is claimed that the engineering time involved in detailing signalling schemes is very considerably reduced by the use of such a technique. In addition, as the packaged units are standardised they can be manufactured while the details of the connections are being worked out.

The geographical circuit techniques to be successful are dependent on the sizes of relays, wire, terminals, etc., used in building up the « packaged units ». The system is, however, very promising and is consequently receiving a great deal of attention in a number of countries.

4.41.412. *What steps have been taken or methods adopted, in addition to those mentioned above, to reduce the costs of drafting the details of an installation?*

As has been indicated in the previous question use is made of permanent standard details of an installation as far as is possible. For example, automatic signal and highway crossing controls and many other such units of an installation lend themselves particularly to standardisation. Generally the mechanical equipment necessary for a layout is standardised, e.g. the connections between point machine and switch tongues, straight and cantilever signals and so on.

It is, however, evident that there has been no significant change in the engineering office practices over a period of years.

4.41.413. *What steps have been taken or methods adopted, in addition to those mentioned above, to reduce the costs of checking of cabling and wiring for internal and external installations?*

A large signalling installation requires a long and laborious test by expert staff before it can be brought into use. This is particularly the case if the layout of tracks and junctions is « tailored » to a particular location and cannot have other than standard principles applied.

The general consensus of opinion seems to be that the only steps that can be taken in this respect is to make the work as easy as possible and the following are a few of those that have been found useful :

1. Train special testing squads for each particular job.

2. Where pre-wiring can be adopted test the pre-wired units in the wiring shop. .

3. If the units can be standardised e.g. automatic signal circuits, highway crossing barriers, etc., special testing panels can be built.

4. Use portable radio sets for communication on the ground.

Again, in some quarters it is claimed that geographical circuitry can, owing to its high degree of standardisation, reduce the overall cost of testing since the packaged units lend themselves to the use of automatic testing panels in the workshops; thus leaving only the outside connections to be tested in situ.

4.41.414. *What steps have been taken or methods adopted, in addition to those mentioned above, to reduce the costs of final inspection and testing of equipment?*

For the final testing and inspection of an installation prior to handing it over to the operating staff there is necessarily some interference with the traffic on the line. From the various countries who have replied, it may be considered that no new methods have been devised for a long time and that the time taken to commission a new installation requires :—

1. Careful planning and co-operation with operating staff.

2. Adequate temporary communication installed for the work e.g. the use of loud speaker equipment, telephone and radio-circuits.

3. If there is any advantage to make use of test panels to simulate point machine operation, etc.

42. *Has modern signalling led to a reduction of the number of points and tracks in the layouts without diminishing their capacity for traffic?*

There are two distinct divisions of answers to this question and these have been partly covered in replies to previous questions. The first division is that when railway traffics are increasing the problem is not to reduce the number of tracks but rather to increase the capabilities of existing track to carry additional traffic and thus save installing more. On the other hand, the second division deals with those countries where complete revisions of requirements are made to obtain a re-assess-

ment of the amount of railway track required to carry the existing traffic under modern conditions. In these cases it is agreed that a reduction in the number of points and tracks can be made without reducing the required capacity. A number of cases can be quoted by the U.S.A. where there has been no reduction in traffic capacity by reducing the number of tracks. In Great Britain, the re-signalling of Glasgow Central Station has enabled ten tracks to be reduced to six tracks while the traffic to be catered for has in actual fact been greatly increased by electrification. Also in Great Britain, when adjacent signal boxes are brought under one central control an examination of the track layout has often enabled adjacent crossovers and junctions to be eliminated, but this has been impossible under manual conditions because of the longer time required to carry out train movements. Sometimes it could be said that it is as a result of the use of both modern signalling and modern motive power units that has enabled this to be done.

43.431. *Do you use any other modern methods or techniques in order to reduce costs of signalling installations?*

When it is possible it is the general opinion that a reduction in the number of types of similar equipment is a distinct advantage and enables a concentration of labour forces on to pre-fabrication of much of the installations. At this point a number of organisations have in addition provided as much as possible equipment in the form of power driven rail drilling machines, diggers, saws and various hand tools, etc., driven from portable generating equipment. They have also provided well equipped messing and sleeping facilities in the form of railway coaching stock or caravans, and trailers. Under these conditions of concentrated effort a greater degree of mechanisation by the provision of light mobile cranes, concrete mixers and so on becomes economic and feasible.

A constant review of existing equipment with the object of making full use of modern methods and materials is advocated, together with adequate research facilities. In recent years there has been considerable development in so-called miniature equipment. It is, of course, a fallacy to consider that a small piece of apparatus to do a certain job is necessarily cheaper than a larger piece, but undoubtedly much can be done in this direction by good designing and advances have been made in a number of countries in this respect. A good example of this kind of work is to be found in the complete new set of relay specifications adopted by the British Railways. These relays are much smaller and cheaper than the previous miniature types available and have the advantage of interchangeability between makes.

43.432. *What organisation do you recommend in order to cut down maintenance and repair costs?*

Maintenance of signalling equipment has for a very long time been carried out by the appointment of qualified men who are allocated the equipment on a section of railway. One or more assistants are appointed with each of these men as required. These men have the responsibility of keeping the installations working, carry out small repairs and renewals and generally attend to failures of the equipment. The larger repairs and renewals are carried out by gangs of qualified personnel sent from a strategically placed depot. These gangs may also be qualified to undertake the installation of new and modern work. All of these men on a district or division are under the control of a supervisor.

With the introduction of modern signalling most of the equipment is readily changed and can be dealt with in central workshops. For general repair and periodical overhauling of the equipment, centralising of workshops to the greatest degree is recommended so that advantage can be taken of production line methods. This

leaves only the day-to-day work to be carried out on the ground.

Beyond keeping the above methods under constant revision and the provision of adequate training facilities for the staff, many organisations do not consider much more can be done. The methods adopted for assessing the amount of work that can be undertaken by individual maintainers can, however, be reviewed and it is of interest to note that British Railways have, by the adoption of Work Study methods, been able to re-assess this work and introduce work measurement to establish the amount of work it is necessary to undertake in maintaining any installation. An incentive bonus scheme is also introduced.

Although the introduction of these methods requires an additional staff for the purpose, the re-adjustment of the lengths of districts maintained by individuals has led to a more than compensating saving in maintenance personnel with a much higher standard of maintenance. On some areas, these methods have enabled a more concentrated effort to be successful in that the individual maintainers have been combined into mobile maintenance gangs under a superviser; these gangs are provided with adequate road transport and specially equipped vehicles for the purpose of reducing the amount of unproductive and travelling time if the train services do not suit.

Summary.

1. It will be appreciated from the foregoing that it has not been possible to indicate what money savings have been achieved by the adoption of most of the modifications which have accrued in signalling designs and practices over the post war years. In many cases the position is obscured by the need for new and additional signalling for the purpose of giving *a*) more safety, and/or *b*) greater capacity. Thus it would be true to say that these two considerations outweigh any others.

2. Modern signalling equipment is being installed all over the world to produce *a*) economies and efficiency in traffic operation, and *b*) personnel savings.

3. Standardisation of signalling equipment is being pursued in all countries which have a home based signalling industry, but it is difficult for those which purchase overseas. Nevertheless, it is generally considered that savings may be made by a greater degree of standardisation from all points of view, including storage, repair, overhaul programmes, and bulk purchasing.

4. Newer forms of relays are becoming available, but generally speaking the signals, signal structures and point operating mechanisms have not changed greatly over the last few years.

5. There has been some mechanisation of methods of installing equipment, but the more widespread use of modern signalling has led to a considerable amount of prefabrication of wiring. This has been facilitated considerably by the use of the smaller plastic insulated cable now available. In turn, it has enabled pre-wired apparatus cases and huts to be distributed and fixed by a specialist gang and is not so dependent on weather conditions.

6. Modern types of main cables with plastic insulation and sheaths do not need the services of highly skilled plumber jointers for finishing off or jointing and they can be laid by signal installing squads, enabling a better use to be made of the men. These cables are being used more and more for signalling and telecommunication purposes.

7. There has been no general significant change in operating voltages over a long period, but more modern practices are using higher D.C. voltages than used to be the case in the past. A change in dimensions of coils has therefore been possible and with newer materials and designs terminal clearances have become smaller. Thus there has been a move towards miniaturisation and a lowering in prices.

8. Electronic units where they are safe

to use have been developed for use in place of relay units and in some cases they have proved to be cheaper than relay equipment; in other cases their use has been for new solutions to old problems. It would appear that the use of such units is gradually increasing, both in quantity and scope of application.

9. Many of the office difficulties of a Signal Engineering Department are receiving attention, since the quantity of work to be carried out in bringing into being large signalling schemes is very great. Any techniques which can be divised for reducing this work makes a considerable reduction in overall costs of the job. Two approaches for the solution of this problem are given by *a*) geographical circuit techniques, and *b*) the use of electronic computers for circuit design.

As a general conclusion it can be seen that under the pressure of work there is a great urge towards adopting shorter and cheaper ways of carrying out signalling and these are being actively pursued in many parts of the world.

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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

18th SESSION (MUNICH, 1962).

QUESTION 8.

Policy and problems relating to the education and training of the staff. Training in safety measures.

REPORT

(America (North and South), Australia, Austria, Burma, Ceylon, Egypt, Finland, Ghana, India, Indonesia, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, Philippines, Siam, South Africa, Sudan, Sweden, Union of Socialist Soviet Republics, United Kingdom of Great Britain and Northern Ireland and dependent overseas territorie),

by Hofrat Dr. Walther Sandig,

Generalsekretär der Österreichischen Bundesbahnen.

I. RECRUITMENT OF STAFF.

As a rule, the recruitment of staff is done in the way of free application and only to a smaller part, new staff is recruited by advertisement of vacancies. The enlistment by advertisement is necessary where the employees needed are not available in sufficient number on the free market. (Conjuncture, shortness of manpower in the special trade or of a certain course of studies, etc.) Recruiting new staff, family members (sons) of the parent-staff are given priority by the Railway Administrations.

On recruitment, the applicants have to prove :

a) *for the lower graded railway service,* on a permanent labour-contract, that they have completed the elementary school (obligatory school = elementary school resp. elementary school and upper-elementary school). Exceptions exist at the Railways of Ceylon, Great-Britain and India, where for the service of unskilled workers no minimum standard of a preliminary education is demanded;

b) *for the intermediate graded railway-service,* in general studies of a secondary school, whereas

c) *for the higher graded railway-service* university-studies and graduation.

Besides, on recruiting craftsmen (lower graded railway - service) the handicraft acquired must be proved.

As a matter of rule, the school-education demanded and the handicraft acquired are to be proved by the relevant documents (reports, diplomas, certifications, etc.) and in exceptional cases in the way of practical examinations (special technical tests)-(Egypt, Japan, Philippine Islands, Union of South Africa, Sudan and Nigeria) or by an employment on probation (as for instance in the U.S.S.R.).

The minimum age limit for candidates

differs from one country to the other, i. e. from 14 years of age (for instance in the Sudan) up to 18 years of age (f.i. in Austria).

With regard to the upper limit of age, there is not only a difference between countries but also between the service-categories themselves, ranging from 25 years of age (f. i. India) up to 55 years of age (Sudan). The upper age limit is, as a rule, much lower in cases of candidates who are to be recruited for the executive traffic service (station master-assistants, train guides, locomotive crew, pointsmen and shunters); for instance the upper age limit for the recruitment of applicants for this service is 25 years of age, whereas for other service-categories 35 years of age are still tolerated (Austria).

To ascertain the physical qualities, the candidates have to undergo a medical examination. — This medical examination is entrusted in most of the cases to the railways' own medical officers and in the other cases to the official medical officers concerned.

Selecting the candidates, many Railway Administrations (Finland, Egypt, Ireland, Japan, Austria and Sweden, etc.) apply psychological tests of aptitude, the so-called test of applied psychology. In some countries, as a matter of principle, all candidates have to pass such an examination of psychological aptitude, whereas in other countries these examinations are only applied on recruitment to certain service-categories in relation with operational safety (for instance in Austria on recruitment of staff for operation-, locomotive-railway-construction- and railway maintenance-services).

These examinations of psychological aptitude are, as a rule, based on the principles of the quantitative test psychology; particularly with regard to intelligence and reaction faculties.

The staff's attitude towards the examinations of psychological aptitude is an absolute positive one, it is well understood that these examinations offer to the Railway Administrations the possibility to select the candidate by objective and scientific methods.

In most of the countries of the English speaking group there are sufficient candidates available for work in all branches of the railway-service.

In places with a big boom, however, a shortage of suitable manpower is for some time experienced, this being caused by the the continually increasing demand of manpower (f. i. in Austria, Sweden, etc.).

Nearly in all countries concerned, a shortage of candidates for the intermediate and higher graded railway-jobs, primarily a shortage of technical experts of all special sections, with secondary school- and university-studies, is experienced. These conditions are partly caused by the consequences of an economic conjuncture, as for instance in Sweden, Austria, etc., or by a rapidly growing industrialization, as in India, Japan, Ceylon, Nyasaland, East-Africa, etc.; besides, it is a matter of fact that technical experts in nearly all countries concerned, being promised better conditions, are withdrawn from the Railways to be taken over by the developing enterprises of Industry. This is facilitated by the fact that these applicants can be offered by the industry, even if not higher salaries, several other advantages, as for instance local employment, no night-work, no transfers, etc.

Whereas in other countries, certain difficulties are encountered by an unfavourable professional strata of the people, thus not allowing to find the sufficient number of suitable applicants for the various trade-employments (for instance in Nyasaland where only unskilled or half-skilled manpower is available on a large scale).

The recruitment of eventually needed rising manpower for the railway-service is carried out, nearly in all countries, mostly by advertisement in the papers, as far as available also in the way of Labour-Exchange, in places where an acute shortage exists, by radio announcement and, in exceptional cases, in the way of television and film and besides by contacting persons in a direct way, in collaboration with the

schools concerned (for instance in Austria, Nyasaland, Sudan, Sweden, etc.).

The wages/salaries of the Railway-staff are, in general, in accordance with the other wages/salaries-conditions of the country. They are, of course, there worse, where too big an offer of manpower for the employment concerned exists (for instance in Egypt for the lower graded railway-service) or where other economy-branches, as a consequence of conjuncture, (ev. also for the purpose of withdrawing staff by offering better conditions) are paying relatively very high wages/salaries (this is the case with the higher graded railway-service in Finland, Norway and in Sweden).

Contrary to it, as a consequence, of a generous and rapidly growing development of economy in some non-European countries, f.i. in Nigeria, East-Africa and in other countries, the salaries of railway-staff are higher than those paid by the economy's enterprises.

Calling in and selecting people for the rising manpower-Staff, in general, special difficulties are experienced by the Railway-Administrations, owing to the country-bound peculiarities : Australia, as also most of the Railway Administrations, is faced by housing-problems, thus the lodging of the newly recruited rising-staff is extremely jeopardized; besides, Australia has to conquer a serious language-problem, since the greatest part of the rising-staff is composed of New-Australians - (immigrants). The difficulties of Nyasaland have their origin in the fact that part of the staff employed from foreign countries returns to the home-country as soon as the contract-period expires, thus creating bad conditions, since up to now well-trained native-candidates are not available in sufficient number and the quality needed.

The poor training-organizations and -appliances have their disadvantageous repercussions on the students of these education-institutes; therefore, Nyasaland will also in future have to rely upon the staff from abroad on recruiting rising manpower.

Very favourable are the conditions in Finland, where a big part of the applicants originates from railwaymen-families, a fact which very soon allows the newly recruited employees an intimate relationship with the Railway-Administration, thus giving them a sincere feeling of railwayman's mentality.

II. TRAINING OF STAFF.

A) At the beginning of the career.

The railwayman has to cope with various professional requirements of the railway-service. The railwaymen's job therefore must be acquired in the same manner as every other trade since only a railway-staff, well trained for its professional tasks, will be the best guarantee of the safety and profitability of the enterprise.

It is not possible to get for recruitment fully trained railwaymen, whereas, as a rule, craftsmen of every kind, and rising staff with the necessary education are available on the free market for all possible trade, commerce-, and industry-service performances.

In general, the railway-staff for the specific railway-service is offered a specialized systematic training, making use of the railway-owned institutions which have been established by the Railway-Administrations themselves.

For the lower graded railway-service, this staff is trained in the way of theoretical instruction and practical introduction; the time required for such a training is very variable, according to the extent and difficulty of work which will be entrusted to that category of employees. The training may be carried out in boarding-classes (released from duty or during the leisure time) as well as besides the regular work of the trainee, under the supervision of a well-experienced railwayman.

For the intermediate graded railway-service the staff, who is normally released from work, is trained in classes for certain service-performances.

The railways' training is imparted the staff of the higher graded railway-service in the same manner; exceptions exist, where

railway-owned colleges and railway-owned universities are established which besides a general technical or non-technical college- or university-education give to their students simultaneously also a railway-service formation (f. i. in the U.S.S.R.).

The complete education in railway-service, i. e. theoretical instruction, practical introduction and practical work between the various stages of education, for the intermediate and higher graded railway-service will last up to 6 years.

The Railway Administrations of nearly all participating countries have established their own institutions, partly railway-owned schools or railway-owned school-centres (Japan, South African Union, Austria, etc.), in order to safeguard the continuity of the education of the currently needed rising staff (Japan, South African Union, Austria, etc.).

The training of the employees is done by classes, held during day-time and in the evening and concerns, in general, only knowledges of the railway-service. But in exceptional cases besides the railway-education there will be put on the instruction-program also general subjects (as in Finland and in Japan), they being : grammar, mathematics and foreign languages, (in Austria, Nyasaland and in the Union of South Africa) : foreign languages, mathematics, geometry, physics and human relations.

With a view to maintain and to increase operational safety and for the purpose of preventing accidents, a sufficient number of lessons is provided in the instruction-plans, sufficient enough to enable the employees to do their jobs on their working places in a safe and accident-free way.

Liable to promotion from the lower graded to the intermediate graded resp. to the higher graded railway-services are employees when they will have had themselves qualified for a higher graded employment by their service-age and their aptitude, proved by performances and examinations passed, although with the exception of such cases where a successful employment on higher graded posts is subject to the preliminary education demanded (f. i. technical secondary school- or university-studies).

The various Railway Administrations give to their especially gifted employees the possibility to be up-graded to superior railway-service by granting them monetary assistance and authorization for the studies concerned (Malaya, U.S.S.R., etc.).

The railwaymen will be re-trained in cases of traction-change, introductions of technical modernisations, of new safety-devices or in the case of a profound change in the enterprise's organizations and others; this re-training will take place, in general, in the form of courses, in the way of theoretical instructions and practical introduction. The existing educational institutions, as railway-schools, training-centres, etc., will — just as suitable workshops — serve re-training-purposes.

The re-training of the locomotive-crew for an other type of traction is only done by utilizing the new motive power as a demonstration-object. A peculiarity is the re-training of the staff of Malaya, where the locomotive-crew is re-trained in the plants of the new motive power-manufactories. Similar conditions exist in East-Africa.

Most of the Railway Administrations consider a centralized management of the entire Education- and Training-Division as a desirable target. Besides, several Railway Administrations are of the opinion that the education of the employees in training centres is to be considered the most ideal solution. (Finland, Japan, Austria, New Zealand, etc.).

With a view to a unified education, special Committees have several times been founded at railway-administration levels, which are charged with the establishment and edition of a unified syllabus and the edition of manuals for special railway-branches. The necessity of a systematic education of the railway-staff is recognised by all Railway Administrations, since without a thoroughly trained staff no profitability and still less the indispensable safety of the railway-operation would be safeguarded.

In the field of railway-staff's education and training, special difficulties are encountered in several non-European countries which are mostly caused by the profound changes of structure of a political, social and economic nature in all participating countries. The Railway Administration of the Nyasaland, in educating and training the staff, is faced by the main-problem of a missing tradition of handicraft in African Companies. A railway-job is for the native only one of the many existing possibilities to gain his livelihood, the result of which is a rather heavy fluctuation among the railway-staff. The education-standards of their schools are still relatively poor. As a consequence of a missing *town*-proletariat rather strong relations with the *country* subsist; thus *country*-bound difficulties induce frequently the employees concerned to leave their service without paying any attention to the time spent already on their education and training. This is also the reason, why no intimate bonds exist between the native and the railwayman's profession.

Recruitment of juveniles as craftsman-apprentices.

Mostly all Railway Administrations of the participating countries are recruiting apprentices (minimum limit of age 13-16 years, maximum limit of age 16-21 years of life), giving them an education of craftsmen, as fitters, mechanics, electricians, blacksmith, tinsmith, installers, welders, in rare cases also as joiners, carpenters, masons, etc.

The apprenticeships lasts, in general, 2-5 years. Exceptions are to be found on the Philippine Islands where people of 20-45 years of age are still accepted as learners in the machine- and mechanical workshops (period of 1 year). In Sweden unskilled staff (minimum 17 years) is recruited for repair works on the rolling stock or on high and low tension-installations; in the U.S.S.R. in all technical professional schools craftsmen of all those trade-categories are educated who will be necessary for the railway-service (minimum age limit 14 years, apprenticeship 1-2 years).

The craftsmen's education is generally given in railway-owned apprentice-workshops or in training-centres or also in technical professional schools which in most of the cases are either attached to railway-workshops or are kept in close relation with them. The number of these training-institutions is in accordance with the current need of rising craftsmen-staff of the Railway Administrations concerned; there exist, for instance, in Great Britain 10 schools with a capacity of altogether 1 000 apprentices, in India 10 training-institutions for 1 500 apprentices, in Japan 28 training-centres for 850 apprentices, in Austria 12 apprentice-workshops for 1 300 apprentices. The craftsmen-schools are, in general, in the various countries, — according to the needs, — dispersed over the entire network of the railways.

The craftsmen-apprentices receive theoretical instructions and are given besides practical education, based on productive labour. During the apprenticeship-period the apprentices have to pass theoretical and practical examinations, in certain stages (f. i semester - examinations and, their apprenticeship being terminated), they have, for the trade concerned to pass the examination prescribed for skilled workers. This terminal examination of apprenticeship is to be passed in the several countries before governmental — and not Railway Administration — examination boards, in other countries before examination-boards of the Railway Administrations concerned resp. their education-institute.

In general, craftsmen-apprentices receive wages, on an apprentice-year's scale, the amount of which is shown in the collective-agreement. Such a wage amounts, for instance, in the Nyasaland, at the beginning of the apprenticeship to 44 %, increasing until the apprenticeship's completion to 66 % of a craftsman-beginner's wage. In the U.S.S.R. the Government grants to the craftsmen-apprentices during the time of apprenticeship in technical professional schools (1-2 years) free lodging, boarding,

clothes and some pocket-money too; during the practical introduction into their trade at the Railways (1 year) they are paid the wage of an unskilled worker.

B) During their career (after their original education).

In general, the members of the various technical services have to undergo a systematic special training, with a view to their future career, comprising, as for instance in Egypt, the staff of the intermediate graded technical service as well as also that of the higher graded service. In other countries, also the members of the executive traffic-service are further specialized. The main reason for this training is in all cases the endeavour to increase on all levels the enterprise's safety and profitability. In Japan, the staff is partly obliged to attend periodically returning training-courses, whereas by the establishment of various courses (also correspondence courses) the other staff is encouraged to continue with its special training. For the senior officers special meetings are envisaged, lasting 5 to 14 days, with a conference lay-out.

The arrangements made for the training of staff consist for the lower graded and the intermediate graded Railway-Service, generally, in a regular theoretical training of the attending groups of employees, who belong to the individual service-units, or of training-centres provided for such purposes, in other cases also of special classes. Such training- and repeated training courses are held, in accordance with the category of the attending employees and the objectives set, in form of expert meetings, expert-discussions, seminaries or as a mere exchange of opinions (Austria).

Concerning the further special training of staff, in most of the countries, save accident prevention, no special subjects are given priority.

The training is given in accordance with the technical needs of the individual groups. But it is admitted that in those countries where technical changes are envisaged and a further perfection of the working-procedure on a new basis is the goal (f. i. change of traction-type, of technical installations and devices, of the safety installations, etc.) or where the rising staff for leadership positions is systematically trained, there will be treated on a priority-scale on the one side the technical subjects in question and on the other side all other subjects concerning human relations, economic sciences, as for instance the technics of management, operational psychology, sociology, economics, etc. (Finland, Austria, South African Union and U.S.S.R.).

Variously, employees who are expected to do higher graded works will be given a preparatory education which is essentially in relation with questions of staff-management, of profitability, etc.

As far as employees are released from work in order to attend training-meetings, they are obliged to be present there.

The employees selected by the Railway Administrations to attend special training arrangements, destined for their continued technical training, receive, in general, their full wages/salaries and also the fees for the courses, for the instructional appliances, etc., are borne by the Railway Administration concerned.

In countries, where own institutions are missing the employees are given the possibility to attend training courses in foreign countries (f. i. in the Sudan). Besides, the special technical training, on a voluntary base, is efficiently backed by the Railway Administrations of many countries by granting several facilities and monetary assistance too.

The members of the traffic-executive (station-staff, train guides, locomotive crew, employees of the technical wagons/coaches-service, safety- and telecommunication-staff and staff of the vessels) have to attend within the framework of the special training the regular service-classes; the employees of the other categories, in accordance with the existing needs, will attend the service-instruction at the time being.

The *regular service classes* are dealing with operation-, safety- and accident pre-

vention-regulations, whereas in the case of service classes *at the time being*, the subjects of the lessons are established in accordance with the service needs, existing at such a time (Finland, Egypt, Great Britain and Austria). In Japan the regular training as well as the training at a time being are even dealing with mental conduct, the style of dressing, with appearance, with the staff's way to talk and to make conversation as well as with customers' service.

The time spent for technical training, including the service-classes, differs very much, ranging from 4 to 40 hours a person and year.

In India every fifth year so-called « refresher-courses » are held which, owing to the needs of the participating groups of employees, last 2-8 weeks.

Partly, either within the framework of arrangements for special training or as extraordinary arrangements also lesson-subjects with the character of general accomplishment, of all kinds, are dealt with. Before all, people are interested in courses of foreign languages, besides also mathematics and physics are taught (in Finland and Australia), in Austria and in the South African Union also instructions in economics, operational psychology, sociology, technics of management are given at the occasion of meetings which are destined for persons of the leadership of the intermediate and higher graded services.

For the purpose of a current training and a continued technical training, in nearly all countries, special appliances are at disposal as demonstration cars, instructional films, signal cabins for instruction purposes, desk models and any other modern instruction material (Australia, Finland, Austria, Union of South Africa, U.S.S.R., etc.).

Employees who are entrusted, within their service work, with tasks of human management (leadership-persons) are getting in most of all participating countries a good preparation for their management tasks. Subjects of the syllabus are psychology, sociology, pedagogics, economics, human relations, public relations and management. To these special courses, in general, employees of the higher graded railway-service are admitted, in exceptional cases (Austria) also employees of the intermediate graded services (foremen, station-master assistants, instructor-officials, etc.). The conferences for the leadership persons are, in general, held at instruction premises which mostly are serving also other purposes (Railway-school-centres, training-centres and Railway-colleges).

All the many and various endeavours, shown in this exposé of the Railway Administrations concerned, with a tendency to procure to their staff the necessary technical education and training, find their repercussions in an extremely high operational safety which only is found with the Railways and not yet attained by any other traffic means in the country. Even if the results of a systematic technical training of the staff cannot be shown in figures, it is quite clear that, without these endeavours and efforts, it would never be possible to put the technical progress into the service of the Railways and to attain the increased service performances which are ascertained by all participating Railway Administrations in spite of a simultaneously decreasing staff. Only by a systematic and continued training of the staff an essential improvement of the customers' service could be realized as well as a decreasing number of traffic- and operation-accidents.

It is true that the current education and training of staff, as stated by Great Britain, is a steady financial burden to the Railway Administrations which nevertheless cannot be eliminated unless a lamentable decrease of quality and quantity of the staff's service performances would have to be faced.

As reported by India, owing to an increased efficiency in the railway-workshops (in relation with the special training of the staff) during the last 2 years, the work could have been done without filling again the forthcoming vacancies of craftsmen-positions.

Japan states that as a result of the technical education and training of staff, it is

proved that the accident figures went down, the existing arrears of work diminished, less complaints were brought forward by the customers and the working-procedures could have been essentially speeded up.

By Sweden is made known that in the way of a better publicity in the service of the customers an increased passenger traffic could have been achieved.

C) Examinations.

In order to prove their technical aptitude, the railway-employees have to pass an examination in accordance with their service-works. Such railway-service examinations are either passed, immediately after the termination of a training-stage, as individual examinations, thus dispensing with a terminal examination or (as in most of the cases) after having finished the entire training-course of a special section, as a comprehensive terminal examination.

Railway-service examinations are considered to be the proof that the employee concerned is capable and responsible to do independently the service demanded, therefore the examination's extent and importance will be based on the service requirements.

The railway-service-examinations are either only oral examinations, or oral and practical or oral, written and eventually practical examinations too. Examinations of less importance have to be passed, in general, in an oral or practical way, before the employee's superior, more substantial examinations are to be taken from an examination-board as far as not subsequent to a training-course (classes) these examinations are taken from the teachers themselves, immediately after completion of the individual training-stages under a special designed chairman of the examination-board (ev. the head of the course himself).

These examination-boards (examination-committees) are, in general, composed of the Chairman and one examiner or more examiners of the special service concerned. As a rule, the Chairman belongs to that service, the examination-subject of which is predominant with regard to extent and importance.

The employees, prior to their admittance to higher graded positions or in the case of a change in their career, are obliged to prove their qualification for the higher graded or changed employment, in general, by the examinations concerned; an exception are those cases where employees had undergone already at the beginning of their service-career a thorough education and training and had proved their qualification in a similar way of examination.

In single cases the employees are offered on the occasion of a changed service the possibility to acquaint themselves with the new conditions and circumstances and thus to qualify themselves in a practical way for the new service which will be entrusted to them (Australia, Finland). Sometimes, employees are only then admitted as teachers for the education and training of the staff (instructors, instructing masters and instructing fellows, etc.), if they have produced the certificate of aptitude on a pedagogical and psychological level (Austria).

It may be considered a rule, that the employees are only accepted to the railway-examinations as specified, if they have completed the education demanded; exceptions are made for the staff of the lower graded railway-service; this staff, already after a short time of practical instruction, will be allowed to perform the service of their own.

There are known also some few cases where it is left to the employee's discretion to prepare himself in the way of self-instruction to pass the railway-service examinations required (Australia, Japan, New Zealand, Austria, etc.).

In some other countries, employees, after having completed a correspondence-course, a controlled or supervised self-instruction, are allowed to pass their service-examinations (Great-Britain, Japan, Sweden and U.S.S.R.).

To certain services — as a rule the service of an engine-driver, of a car-driver or of a boiler-attendant — the employees are

only admitted after having passed an official (State) examination. These examinations are, in general, not to be taken before units of the railway-service, but before the authorities concerned and, only in exceptional cases, railway-bodies will be entitled to take boiler-attendants' and engine-drivers' examinations (in Austria-Railway-Supervisory Authority).

Besides, special stipulations are existing, as for instance in Australia, where employees in charge of cranes and weighing-machines, are examined by a State-Examination-Board (Ministry of Labour and Industry).

III. ADDITIONAL INFORMATIONS TO CHAPTERS I AND II.

The comprehensive dealing with questions of principles concerning the staff's education and training, is entrusted at the individual Railway Administrations to a Central-Office. In most of the cases this Central-Office will be a division (Referat) within the Administration or Personnel-Department of the General Direction of the Railway Administration. For instance it is the Education- and Training Division of the British Railways which decides and establishes the general education- and training-policy of the British Railways; this division il also responsible for the centralized training of the senior-staff (higher graded appointments) and for the training and education tasks which cannot be solved by the regional Headquarters or where collaboration cannot be dispensed with. Similar conditions exist in Austria. In other countries a central division for the staff's education and training is pending creation. In New Zealand for instance it is the Personnel-Division of the office of the General Director, which is mainly in charge of the staff's training for the traffic-service, whereas the other staff is trained by the technical services concerned.

In the U.S.S.R., it is the Head-Department of Education-Training of the Ministry of Communications which is charged with the organization of the courses with the tendency to increase the qualification, as well as with the preparatory courses; the subordinated Headquarters have their own divisions to which the education and training of the staff is entrusted as far as their own sphere is concerned.

The documentation for education and training as well as for the staff's examinations is established in collaboration with the relevant responsible Central-Office, together with other technical services. Besides, if necessary, service-branches are putting at disposal their own experts as teachers resp. as members of examination-boards; they offer also their help for the preparation of the instructional appliances needed.

The education and training of the staff as well as the holding of examinations is laid down in special service-directives which are published either in the form of « service-regulations for education-, training- and examination-matters » or in the way of service-orders provided for such instructions (*Official Gazette, Information Bulletin*, etc.).

It is the eminent importance of a thorough special education and training of the railway-staff which convinced the Railway Administrations of all member-countries to create on a rather large scale railway-owned institutions for education and training to serve the purpose of the personnel's instruction.

In addition to the railway-education-centres there are in nearly every country, in accordance with the existing needs, also at disposal : railway-schools and, in the field-service, instruction-rooms too.

In the U.S.S.R., railway-universities, railway-colleges, technical professional schools (evening classes) and technical schools for education and training of the rising staff, who is to fill vacancies of the higher, intermediate and the lower graded railway-service, are in existence.

As a matter of fact, the railway-central-schools resp. the railways' schools (Railway-Institutes) are run as Boarding schools.

The Austrian Federal Railways have their own Railway-Academy (Federal Railways'

Academy), the main-task of which is the education and training of leadership-staff for the intermediate and higher graded railway-service.

With regard to other instructional facilities, it is to be said that the Railway Administrations have partly at disposal their own demonstration-cars (Australia, Finland, Austria), laboratories (Japan), signal boxes and model-desks for instruction-purposes (Ceylon, India, Norway, Union of South Africa and Austria) and still other auxiliary means for instruction, as facilities and documentation for teaching and learning, service-documentation, photos, films, etc.

As a rule, the railways have their own instruction staff (instructors), whose only task is the education and training of the staff. Only in rare cases, full-time instructors are not available; in this case it is necessary to entrust the tasks of the staff's education and training at the time being to expert-officials.

In addition to the full time instructors (officers who are not charged with other work than the education- and training-tasks) also qualified experts are invited, at the time being, to partake in the education and training of staff.

Employees whose exclusive activity is the education and training of the staff (instructors) are carefully selected among the most capable experts concerned whose adequate special knowledges and experiences as well as their pedagogical qualities must be of a very high level.

The way of selection is a different one : In some cases the selection is made on the base of practical probation, of a good general education, after having been watched for some time; in other cases as a consequence of tests of psychological aptitude, thus having ascertained, by employing scientific methods, the pedagogical and personal qualities and gifts of the teaching staff. For the selection of instructors there are provided in the individual cases special arrangements (as for instance in Australia a Ministerial Examination Board, or in Austria an examination-service) in order to prove in a psychological way their qualities and aptitude.

As a rule, the instructors are prepared for their tasks as teachers in the fields of pedagogics, of psychology and of sociology. The education-methods are differing with the individual Railway Administrations. This education is partly administered in an unique course and in other cases in stages with certain periods between; for these instructions, education premises are made available, as for instance in Great Britain the Transportation-School at Darlington and in Austria the Federal Railways' Academy.

The instructors of Nigeria have to undergo in Great-Britain a systematic education in all pedagogical fields.

In general, teaching-staff, not belonging to the Railway, will not be entrusted with the technical formation of the staff, whereas the Railway Administrations admit such persons for training their staff in other subjects, as foreign languages, economics, management-technics (human relations, public relations), sports, etc.

In the railway-schools (training-centres, central-schools, railway-institutes, etc.) one teacher handles about 20 to max. 25 trainees, in exceptional cases (in relation with the extent and the difficulty of the instruction-subject) the number of the course-members decreases even to 10. But contrary to it, there are also exceptions; one course is being attended by 30 to 35 trainees.

Only few of the participating countries have stated in a concrete way the financial expenditure made for the purpose of the staff's education and training. The data at disposal allow the conclusion that the costs for this purpose are sometimes quite essential; they differ from 0,4 % (Finland) to 6.5 % (Japan) of the operational expenses.

Nearly all partaking Railway Administrations re-examine their employees of the executive traffic service within regular

periods (1-2 years) with regard to their knowledge in service regulations concerning operational safety and accidents' prevention. In several cases, these employees have to attend so-called « refresher-courses » (for instance in Australia once a year, in India every fifth year).

In Japan, the knowledge of service-regulations and their strict observance are only safeguarded in the way of a current instruction and training of the employees and by a permanent control, whereas the intellectual and physical qualities of these employees are examined three times a year.

Employees who fail such an examination, are withdrawn from their job and only, after having passed a repeated examination, will be again admitted to that trade. Should they fail again, they will be definitely given another work.

As a special problem, *Egypt* is faced by the necessity to train and re-train, within the shortest possible time, quite a substantial number of employees for Diesel-traction. *India* has at present difficulties in the course of the introduction of unified education/training-methods in the schools of the Indian Railways which are dispersed all over the country. *In Norway* priority is given to the solution of the question in which way the employees may be fully convinced of the necessity and importance to adhere strictly, in their own interest, to the accident prevention-regulations and to utilize the protective clothes, they have at their disposal.

[621 .335 & 621 .431 .72]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

18th SESSION (MUNICH, 1962).

QUESTION 4.

Safety and automation on electric and Diesel motor power units.

Application of automation techniques in the driving of power units (locomotives and motorcoaches), automatic starting, control of the spinning and skidding of the wheels, automatic transmission of the signal indications and automatic stopping : vigilance and dead-man's devices; application of electronics.

REPORT

(America (North and South), Australia, Burma, Ceylon, Egypt, Finland, Ghana, India, Indonesia, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, Philippines, South Africa, Siam, Sudan, Sweden, Union of Socialist Soviet Republics, United Kingdom of Great Britain and Northern Ireland and dependent overseas territories),

by Dr. F.T. Barwell,

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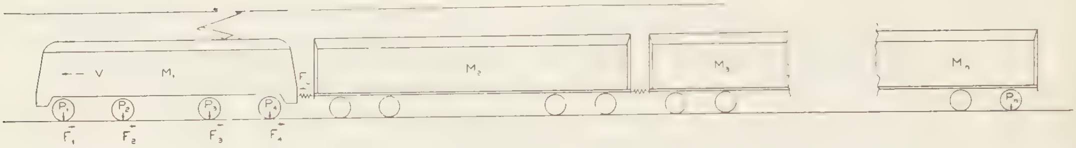
SECTION I. — INTRODUCTION.

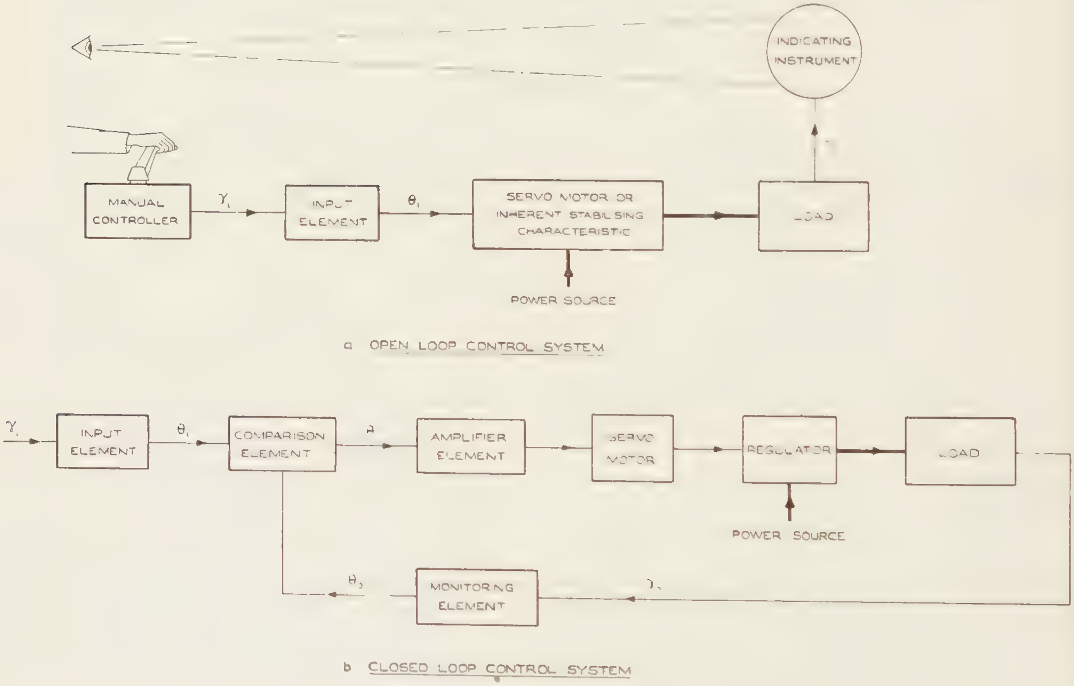
From the point of view of control engineering, the train may be regarded as a system of coupled masses as shown in figure I.1 subject to a variety of retarding forces which have to be overcome by tractive forces applied to one or more axles or transmitted through draw and buffing gear. For our purposes, motion parallel to the rails in a straight line will be considered but it must not be forgotten that departures from a Newtonian path are deliberately imposed where curves are being negotiated and occur parasitically even on straight track. This will be ignored except in so far as the energy necessary has to be provided by additional tractive force.

Control systems may be broadly divided into two categories, open loop and closed loop as indicated in figure I.2. The concept of feed-back is clearly shown in this figure where the information regarding the actual condition of the load is fed to a comparison element where it is compared with the control or command indication. The open loop control system often referred to as an unmonitored system, embodies a component, for example a series wound traction motor which has an inherent regulating feature. Where an installation does not provide a completely closed loop it might be considered as a closed system if the human operator is regarded as carrying out a control function, e.g. moderating the output of the machine by reference to



$M_{1 \text{ to } n}$ = Masses of coupled vehicles;
F_c = Force at coupling;
$P_{1 \text{ to } n}$ = Normal force between wheel and rail;
$F_{1 \text{ to } n}$ = Tangential force between wheel and rail;
α_1 = Acceleration of locomotive;
μ = Coefficient of adhesion = $\frac{F_1}{P_1}$, $\frac{F_2}{Ps}$, etc.;
$\Sigma F_1, F_2, F_3, F_4 = F_c - F_R - M_1 \cdot \alpha_1$
Where F_R = Sum of aerodynamic and frictional resistance to motion of locomotive itself;
$F_c < (P_1 + P_2 + P_3 + P_4) \times \mu - F_R - M_1 \cdot \alpha_1$;
V = Speed of locomotive.

Fig. I.1. — Diagram illustrating notation.



γ_i = Input quantity — set or varied by external agency to determine condition of controlled member;
γ_o = Output quantity — physical quantity defining actual value of controlled quantity;
γ = Deviation (or « error ») ($\gamma_o - \gamma_i$) — the instantaneous difference between output quantity and input quantity;
θ_i = Converted input quantity — physical quantity related only to input quantity e.g. voltage representing desired speed.
θ_o = Converted output quantity — physical quantity related only to output quantity;
$\theta = (\theta_o - \theta_i)$ = Converted deviation — physical quantity related only to deviation.

Fig. I.2. — Basic control circuits.

an indicating instrument. In the treatment of our present subject, each system will be regarded as a closed loop and the degree of automation assessed by the variety of demands made on the activity of the human operator.

A further development of the control system is known as the adaptive control system. In its simplest form a second loop is provided which governs the target set to the basic control system on the basis of previous operations. It can be developed so as to seek an optimum result in the presence of a number of unco-ordinated variables. This is the equivalent of the behaviour of an experienced driver who learns to moderate his controlling action in the light of his previous experience.

The simplest form of control often used to regulate the temperature of ovens is the on/off control. Here, when a temperature falls to a certain point, heat is switched on and when it reaches a predetermined level it is switched off. Such a control can only keep the output quantity between the two limits within which it fluctuates in a saw-tooth manner. Therefore for finer control it is generally arranged for a control signal to act continuously. It is possible, however, to obviate the disadvantages of a discontinuous control if the correcting action may be so proportioned as to bring the controlled quantity to the desired value rather than waiting for it to overshoot the mark as in the simple system. The mathematical treatment of discontinuous systems is extremely complex and the reader is referred to (8) (11) for a detailed review of developments. Application to railway working is described in Section VIII.

Reverting to figure 1, the maximum value of tractive effort which can be exerted is determined by the condition that it shall not exceed the product of the normal load of wheel and rail and the coefficient of adhesion. This former quantity may vary as a result of distribution of forces and loads within the appropriate vehicle (10) and the latter quantity varies widely with atmospheric conditions associated with the degree of contamination of the rail. The masses of the train may vary from time to time according to traffic conditions, the resistance due to axle boxes may vary with temperature conditions, etc., aerodynamic resistance with wind velocity and direction, and the elastic nature of the coupling between vehicles will limit the safe rate of application of acceleration and retarding forces. All these variables must be brought into account in order to enable the motion of the train to confirm with the desired pattern and explain why the successful driving of the train calls for far greater skill and experience than, for example, that required to drive a motor car.

In the present report, the application of automatic methods will be dealt with in the following order : the control of F generally and then in relation to μ; the next stage is the relationship to track occupation conditions firstly in association with a manual link and secondly regarding the safeguards employed in the event of a failure of that link. Means whereby the human operator can monitor and control more than one coupled unit are described and finally complete automation is discussed wherein the human link is either eliminated or restricted to an overall supervisory function. Undoubtedly, electronic methods will be increasingly employed in modern automation and the paper concludes with reference to experience in their use under railway operating conditions.

SECTION II.
AUTOMATIC ACCELERATION.

The tractive effort which can be exerted by a motive power unit is governed by the two limits shown in figure II.1. Firstly a horizontal line which represents the limit of adhesion and then a hyperbola which represents the maximum power installed. It is possible that the equipment fitted may in fact be unable to exert the torque required to exceed the adhesion limit but as previously stated, this limit is exceedingly variable and means must be provided either automatically or by action of the driver

to prevent this limit being exceeded, otherwise serious consequences may result including destruction of the motor by overspeeding and severe damage to the rails. Similarly, due to design or inherent feedback the motors may not always be able to utilise the full power available during

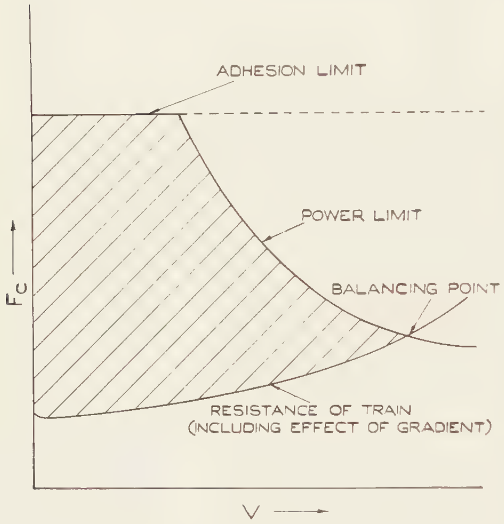


Fig. II.1. — Tractive effort. — Speed limits.

the parabolic portion of the curve. This power itself may be variable in so far as in the case of electric rolling stock the limitation to the power which can be used is determined by the heating of the motors or associated control gear. Thus, more power may be used for a short term than continuously.

In operating a train, it is clearly desirable to select any point within the shaded portion of figure II.1. Except at the balancing point, i.e. when the tractive and resistance forces are completely in balance, it will be necessary to move this single point continuously, either during acceleration where a horizontal locus will be required or when the desired speed has been attained, tractive effort should be reduced to balance applied resistances without leaving a margin for acceleration. It is clearly undesirable either for a manual operator or an automatic control mechanism to be continually operating and therefore it is desirable to select the locus rather than a separate operation for each step from point to point. Practically all modern locomotive power units are driven by series motors having characteristics of the general type shown in figure II.2. These have an inherent feed-back characteristic in so far as the current passing when a constant voltage is applied to the terminals represents the difference between that voltage and the back e.m.f. which is directly proportional to speed. Thus, as speed increases, torque diminishes until a balance is achieved between tractive effort and tractive resistance. By varying voltage, it is possible to set up a network of control conditions as shown in figure II.3, *a* and *b*. It is usual practice for only a limited number of voltages to be available and we therefore have a discontinuous control system. Thus, during the acceleration period, the tractive effort can be controlled only between limits; as the train accelerates it will fall off until the speed appropriate to the maximum point of the next step or notch. Thus, the nearest approach to a horizontal locus will be a saw-tooth curve. The simplest control therefore would consist of an ammeter showing motor current; the driver would watch this ammeter stepping forward notch by notch as the current fell to a prescribed value, the design of the notching steps being such that on moving from one notch to the next the maximum current would not exceed a certain value.

Additional loci may be obtained by weakening the motor field. An alternative method of control would be to use a shunt motor and regulate the field. This would give horizontal speed-torque loci but would be less stable in response to variations in applied voltage.

The instructions to the driver governing motor current would be determined by the designer from his knowledge of the current-carrying capacity of the motors which in

turn he would design so as to correspond with the adhesion limit. Nevertheless, the driver would be prepared to reduce current if he found the locomotive were slipping. He would do this; for example, were all motors fitted with ammeters; he could then compare one with another. He would also moderate his tractive effort from his knowledge of the make-up of the train and of the elastic nature of the coupling between the vehicles.

In the case of A.C. locomotives, numerous voltages are attainable by selection of different tapping points on the transformer. Thus in figure II.3*a* there are 40 speed-torque loci which can be selected. Because of the transformer action, each of these may be regarded as economic and may be run on indefinitely. In the case of D.C. locomotives, different running loci are determined by the insertion of resistances in the main power circuits. The energy dissipated in these resistances represents a loss of efficiency and the heat generated cannot be withstood indefinitely. Therefore, the only condition which is economic and suited for indefinite running is when the resistances are entirely removed from the circuit.

Where two motors are involved in one

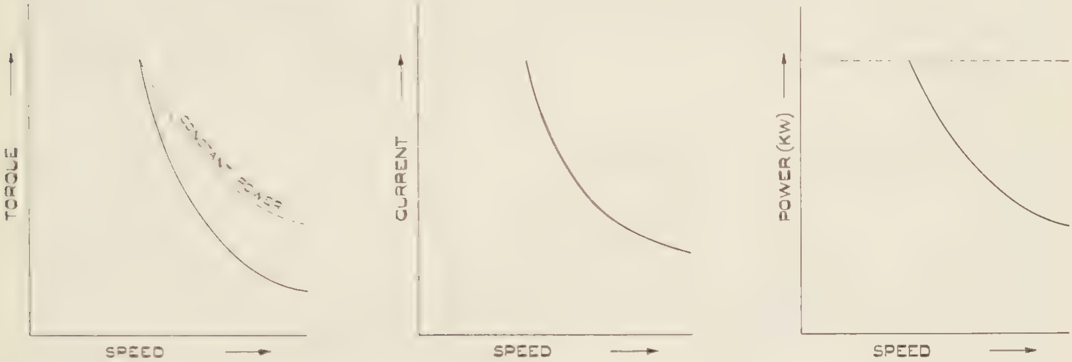


Fig. II.2. — Series motor characteristics.

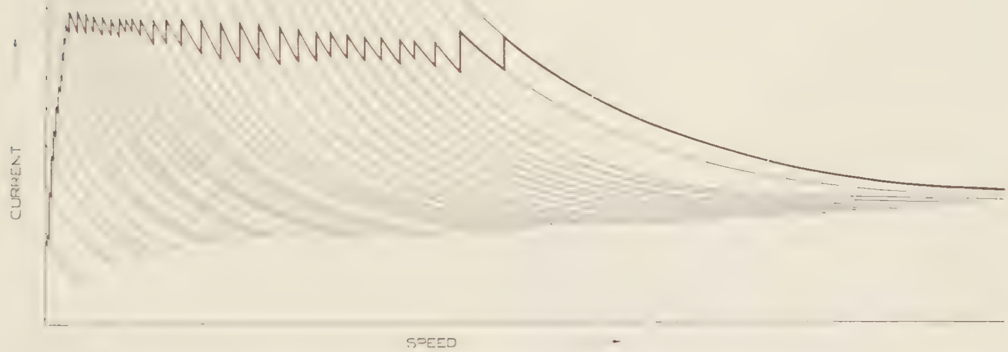


Fig. II.3 (*a*). — Control network of A.C. system.

control group, it is possible to halve the voltage across each by putting them in series and to obtain a second economic control locus by placing them in parallel. There are thus two economic loci. Where multiples of the two motors are involved, it is possible to obtain further economic loci by rearranging motors in various combinations of series and parallel connections.

low that slipping could not occur, the performance of the machine would be handicapped to a prohibitive extent, only light trains being capable of being handled. A heavy train requires the maximum utilisation of the adhesion and because this is so variable a quantity, manual control is desired so that a limit can always be approached but not exceeded. The writer does not regard this as an argument against

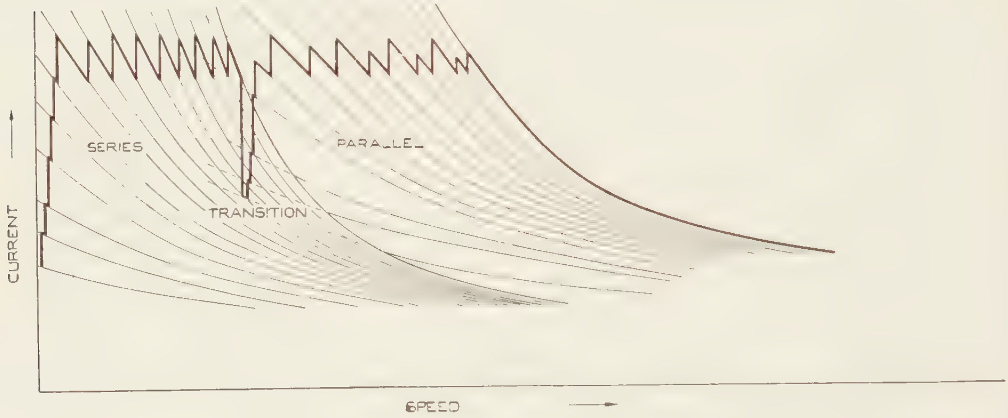


Fig. II.3 (*b*). — Control network of D.C. system.

automatic control as such but merely as indicative of the need for an additional control function.

The replies from the various administrations show varying degrees of automation. In some cases, it is stated that automatic acceleration is fitted to multiple unit passenger trains where there is a constant make-up but not to locomotives where considerable variations in load are encountered. Your Reporter does not consider this to be a fair statement of the problem because the utility of automatic control apparatus is greatest in assisting the driver to deal with variable conditions rather than coping with the constant conditions. It is probably fairer to say that because multiple unit passenger equipment is not critical from the adhesion point of view, it is possible to design the control value of tractive effort to lie well within the adhesion limit. Thus, control of motor current is all that is necessary. On the other hand, if in the locomotive case, control value were set so

Multiple unit electric trains.

It is general practice to have automatic control of notching in multiple unit trains.

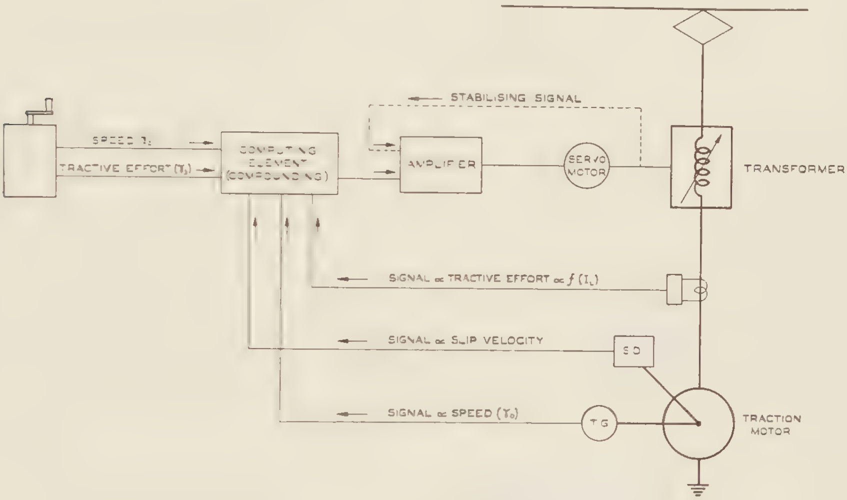
On D.C. systems, series-parallel control is always used to increase the starting efficiency, although the same object can be achieved by a well designed single combination arrangement. On A.C. systems, the voltage of the motor is varied by providing a number of tappings on the transformer and changing from tap to tap as acceleration of the train proceeds. These arrangements result in the speed tractive effort curves illustrated by figures II.3*a*. and II.3.*b*.

It is the general principle to change

from one curve to another when the current has fallen to such a value, that when the tap change is made or the series resistance shorted, the current will rise to the predetermined value. It is now general practice to design the curves so that with the same lower value at which notching is initiated the current jumps decrease as the speed is increased to allow for the lower effective adhesion at higher speeds. The general practice is to measure the motor current by an electromagnetic relay and to use this relay to initiate the step to the next curve.

At first sight it would appear that, to give consistent timings under all conditions, the initiation of notching should be on a time or acceleration basis, but it has generally been found that under conditions of crush loadings or equipment cut out the resulting overloads are intolerable and that the errors caused by operation on a current basis, even under very adverse conditions, are quite tolerable.

Thus, relating to figure I.2, the output γ_0 is not monitored but the motor current which is related to it is as indicated in figure II.2. Thus the current to the relay is represented by θ_0. The setting of the relay is equivalent to providing a fixed value of θ_1, i.e. when the current falls sufficiently below this value θ exceeds a predetermined quantity and the relay operates in the prescribed sense. The system is one-sided in so far as the relay will not operate when θ increases in the opposite sense, e.g. when current increases.



$f(I_L)$ = Function of load current;
$\gamma_i = (\gamma_2 + \gamma_3)$ = Input quantity;
γ_0 = Output quantity;
SD = Slip detector;
TG = Tacho generator.

Fig. II.4. — Control diagram for A.C.

Figure II.4. shows diagrammatically the probable form taken by a full automatic control system embracing tractive effort and speed control with overriding slip control.

The above system is often refined by providing a second or alternative relay setting which the driver can select to suit

traffic conditions. He can thus choose two values of θ_1.

The replies to the questions reveal the following :

ten administrations operate multiple unit equipments, 8 400 D.C. and 450 A.C. equipments;

London Transport also operate 2 470 D.C. equipments and the U.S.S.R. an unspecified number;

two administrations operate both D.C. and A.C. multiple unit electric stock.

One administration uses manual control, one uses both manual and automatic current control. Seven administrations use automatic current control and one uses time control (J.N.R.).

All administrations use step by step and only three quote figures — first notch 180 kg/ton and notching 5 250-6 600 kg.

Regarding the reason for adopting automatic control, accurate time schedules interest five administrations, simple driving interests three administrations and minimum resistance rating interests one.

Six operators permit the driver to override the automatic control and one does not.

The U.S.S.R. states that automatic control is always desirable.

Regarding indication available to the driver, two operators provide an ammeter, one provides an ammeter and a speedometer, one provides a speedometer and one provides a loadmeter. The rest provide no assistance to notching.

Five operators allow sequence to be arrested when required in shunting, series, and parallel, and two provide no such facilities.

Three operators provide two settings; the others do not provide alternative.

One administration, T.G.O.J., provide thermal tripping of auxiliary machine overloads only. Japan provides thermal protection in power circuits.

Only the U.S.S.R. provides regenerative braking in four steps. None notes the use of rheostatic braking. N.S.W. operate a few regenerative braking equipments.

N. B. — T.G.O.J. : « Trafikaktiebolaget Grängesberg-Oxelösunds Järnvägar ».

Electric locomotives.

Electric locomotives employ in general the same power circuitry as is employed on multiple unit equipments.

Generally, the driver is able to take each step at his discretion. Where the locomotives are equipped with individual air or solenoid operated-contactors this is done by a control wire from each step on the master controller to the contactor concerned. With the extending use of cam shaft control, however, where an electric or pneumatic motor controls the sequence of power contactors, a system of control has grown up where the driver starts the cam shaft motor by moving his handle, to an operating position and the motor continues to sequence notch by notch until the driver returns his handle. Notching back is similarly performed and the driver, by a similar manipulation, may take one notch at a time. An ammeter is provided to guide the driver in his notching. Manual control has been found desirable on locomotives because the wide range of tractive efforts at which control may be required to suit train loading and gradients is such that a relay capable of performing the duty would not be simple.

The replies to the questionnaire show as follows : nine operators between them employ 1 170 A.C. and 1 540 D.C. locomotives. The U.S.S.R. do not answer but would appear to have a large number. Two administrations only use automatic current control acceleration and then only on a few new locomotives. Two use automatic time control with provision for manual overriding.

All use step by step control with maximum changes of tractive efforts ranging from 8 % to 25 %.

Four railways provide some form of indication that current is on in standstill condition, two issue specific instructions to drivers; six do not comment on the question. For operation on the short time rating of the electrical equipment, only one operator provides a thermal trip in the main power circuit. Another provides an over-voltage

tap on the transformer. This tap is used for a short time, as in recovery time, but overload for a long period is prevented by a temperature relay on the transformer.

Diesel electric locomotives.

As controlled excitation of the generator is invariably provided, there is no need for power notching but other needs arise :

i) the rated horsepower of the Diesel engine at any speed must not be exceeded;

ii) the excitation of the generator must be varied so that at all locomotive speeds the volts and amps are such as not to overload, the Diesel engine at the r.p.m. at which it is operating;

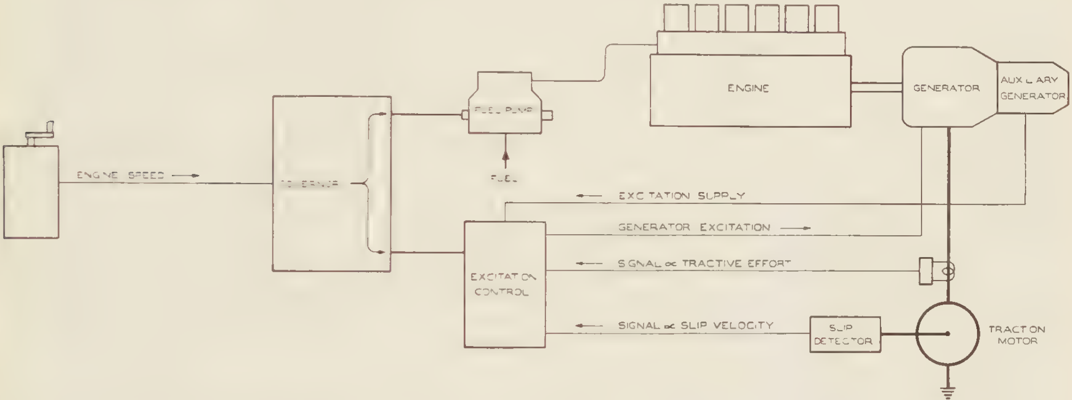
iii) at low speed of locomotive, the power may not be able to be absorbed without a motor current so high that the locomotive wheels may be caused to slip;

iv) at high speed of the locomotive, the power of the Diesel may be too great for the generator to absorb because of high voltage causing overheating of the generator field.

Two schemes, quite different in conception, to perform these separate needs have been evolved :

1) inherent characteristics of machines or generator excitation are arranged so that the power absorbed is at all times just less than the ability of the prime mover to provide and a governor controls the fuel input to give the required r.p.m.;

2) at low train speed, a fixed excitation is applied to the generator or sometimes the excitation is under automatic control to give constant current.



Governor secures predetermined power for each engine speed setting by regulating both fuel input and power output therefore to control power driver selects engine speed only.

Governor controls both fuel input (by fuel pump) and power output (by generator excitation), the governor being designed to keep both in balance at any selected output setting.

Fig. II.5. — Control diagram for Diesel electric.

For constant power running, a fixed fuel input to the engine is set and the engine governor is used to control the generator excitation to absorb all the power offered to give constant r.p.m.

At high locomotive speed, the generator operates at fixed excitation and the governor controls the fuel.

The problem is an example of closed loop control with several variables, as set out diagrammatically in figure II.5.

In both the above cases, a series of characteristics is provided to give variable loco-

motive performance and the driver selects on an 8 or 10 point controller the characteristic to match the locomotive to the job being performed. On modern systems the controller is continuously variable and the characteristic selected is one from a whole bandwidth of characteristics. An ammeter is usually provided but except when no current control is provided it serves only as a check to the correct operation of the automatic equipment.

The replies show as follows :

eleven operators use 1924 Diesel electric main line locomotives and one does not specify the number. Two operators provide a few new locomotives with continuous control and all others with manual notching with some form of load regulation. An ammeter is generally provided as a check. Ten railways use a load control system where the engine governor controls the generator excitation to give constant speed on constant fuel quantity. Two railways use a matched generator excitation system, one railway operates both systems. (Within the ten using load control, there are various proprietary control systems but they are alike in principle.) Two railways with load control use a continuously variable speed range but the majority only give a few discrete settings and only one uses automatic control of the maximum current.

Only one operator is stated to use rheostatic braking. On both electric and Diesel electric locomotives, there is little doubt that if automatic overriding slip control on a basis of continuously variable current control were available, manual control of notching on electric and Diesel electric locomotives would become obsolete.

Diesel hydraulic locomotives.

These locomotives are equipped with an hydraulic torque converter between the engine and the locomotive wheels. The actual hydraulic torque converter itself is only efficient over a limited range of speed and it is augmented by either a multiplicity of converters or a multi-speed gearbox.

In one example, a control system operated from a speed governor causes automatic gear changing to take place up or down as required when the speed differential between input and output of the converter is outside the economic range. No attention to this from the driver is required. For any one engine speed the locomotive will accelerate from standstill to full speed with a continuously decreasing torque.

The driver operates a controller which sets controlled r.p.m. of the engine. On some locomotives, a number of discrete settings are given from idling to full speed and on others, this setting is continuously variable. This results in a starting torque which is a function of the controller position and as locomotive speed increases, the power available is a further function of the handle position.

Six administrations operate 335 locomotives of this type. All have manual control of notching steps with automatic gear change. One administration uses on many of its locomotives continuous control in place of discrete steps. This appears to be necessary in starting heavy trains on grades when working near the adhesion limit. On four administrations, engine tachometers are provided to assist drivers in control.

Diesel railcars.

Three types of railcar drives are considered, electric, hydraulic and mechanical.

Those with electric drive generally follow the principle of control of the Diesel electric locomotive with a torque control arrangement, and a few notches on the controller for driving convenience. The Diesel hydraulic and Diesel mechanical drives are very similar to the hydraulic drive which acts in place of the clutch on the mechanical drive. Most are driven on a throttle control and the driver changes gear by a gear lever when the engine speed requires it. A tachometer gives the speed of one of the engines and the others will all be at the same speed. This tachometer is usually marked with a band to show both the maximum speed at which a change up must be made to avoid engine overspeed, and

the minimum speed at which a change down is required to maintain traction.

Seven administrations operate railcars, of which :

1 operates 84 Diesel electrics;

4 operate 2 300 Diesel mechanicals;

3 operate 2 300 Diesel hydraulics;

1 operates 588 unspecified (some are electric as an ammeter is provided).

The following points are interesting :

only one railway was stated to operate Diesel electrics (B.R.);

one railway operates over 2 000 Diesel hydraulics (Japan);

one railway operates over 2 000 Diesel mechanicals (B.R.);

The absence of automatic features is probably explained by the fact that these railcars cater for a traffic of a type where minimum capital expenditure on rolling stock is essential. Several administrations state that automatic acceleration is too complicated for railcars.

Diesel shunters.

Nine administrations replying operate between them :

1 323 Diesel electrics;
280 Diesel hydraulics;
500 Diesel mechanical shunters.

Ninety per cent of these are on one railway (B.R.).

The electrics are the most popular and these probably comprise the lower horsepower units. This is because the electric drive, although specified as manual and step by step (no administrations report any other system) has built in a load control system which is ideal for shunting duties. Ammeters are provided in electrical systems and tachometers in mechanical and hydraulic systems for guidance of the driver.

Continuous control of voltage.

British Railways are running trial equipments on A.C. designed to avoid the tractive effort peaks inherent in a notching system and to prepare the way for more precise current control and slip control.

In one scheme on trial on a multiple unit equipment a centre tapped choke is connected to transformer taps and the centre tap supplies the motors. This choke is continuously variably excited in such a way that it either bucks or boosts the transformer. This choke is stepped from tap to tap by an orthodox transformer tap changer, and this arrangement gives a continuously variable voltage from zero to maximum.

In a second scheme developed for use on a locomotive, an orthodox tap changer is employed and D.C. excited saturable chokes are connected in series with the taps capable of bucking the tap voltage and being controlled to increase the voltage gradually to the next tap when the chokes are switched next tap ahead. By virtue of the rectifiers inherent in the saturable choke circuit the tap changing can be made without any appreciable current interruption.

Two further trial equipments are being studied without any power switching. One of these is with an induction regulator insulated for 25 kV and acting as combined transformer and continuously variable voltage supply to the motors.

In the second trial, the well-known moving coil regulator principle is used. In this scheme, the transformer has a long limb and a short circuited coil forces the magnetism into the air. A coil (secondary) moves from a position linking no magnetism to one with close linkage giving continuously variable voltage.

SECTION III. — WHEEL SPIN AND SLOW-UP DETECTION AND CONTROL.

The coefficient of adhesion is probably the quantity in railway dynamics which varies most (6) (16) and whilst the mechanical and electrical design of the motive power unit takes this into account as far

as possible, numerous administrations have found it desirable to embody automatic controls which act when this value is exceeded; in some cases during traction and in other cases during braking. The consequences of an uncontrolled wheel slip at starting are severe damage to the rails sometimes referred to as « rail burning ». In addition to this damage, danger exists that the rail at this location may become more subject to fatigue cracks. Even though the damage may be repaired by welding, the danger of fissures persists.

If uncontrolled sliding occurs at speed, the effect on the rail is less serious being spread out over a considerable distance but the risk exists of an armature itself becoming damaged due to excessive centrifugal force.

Loss of adhesion between wheel and rail during braking may lead to a locked wheel and the occurrence of flats on the tyre. The subsequent trueing up of the tyre involves the removal of material equivalent to wear which would occur over many miles. Moreover, the coefficient of friction between a locked wheel and the rail has been shown to be very much less than that between a rolling wheel so that when « wheel-lock » occurs or is imminent, the braking distance of a train is considerably increased with corresponding impairment of safety.

Table III.1. summarises the views of 15 administrations :

TABLE III.1. — **Importance attached to relative aspects of adhesion problem.**

	Order of merit	*Points (max. 4)*
Electric vehicles . . . . (10 administrations)	1 loss of traction	3.3
	2 rail wear	1.3
	3 motor flashover	1.2
	4 motor overspeeding	0.8
Diesel electric vehicles . . . . . . (5 administrations)	1 loss of traction	2.9
	2 motor flashover	1.4
	3 motor overspeeding	1.3
	4 rail wear	1.2

To construct this Table, a points system has been used based on an order of merit. For each administration 4 points are awarded to first choice, 3 to second, 2 to third and 1 to fourth choice since there are only four types of trouble mentioned. The average points were then calculated.

South African and Indian Railways, the only administrations to answer specifically for Diesel hydraulic locomotives, both state that cardan-shaft damage is the most serious consequence of wheel slip.

There are no answers, except from British Railways, specifically related to electric multiple unit stock. These units operate relatively satisfactorily at moderate va-

lues of adhesion and motor damage is the worst consequence of uncontrolled wheel spin in this type of service.

Thirteen administrations give the values they expect for starting adhesion. Some give an assumed value but others give a range in which case the average or mean value is noted. The spread of values is shown below :

TABLE III.2.

Range of adhesion	*No. of administrations within range*
.235 — .255	4
.255 — .275	3
.275 — .295	3
.295 — .315	2
.315 — .335	1

As can be seen, most values are assumed to be between .24 and .29 inclusive. Indian, Swedish and Indonesian railways assume the highest values.

The following administrations commented on the question of variation in adhesion (from place to place and from time to time) :

Russia — Adhesion can fall below 0.2.

Nyasaland — Some trouble during three months wet season.

New Zealand — Adhesion seriously affected by rain, and never wise to assume greater value than 0.18. Leaves give some trouble.

Ghana — 15 % adhesion in the early morning due to presence of water droplets.

T.G.O.J. — Adhesion varies from 0.18 to 0.35.

Only 5 administrations state that weight transfer is taken into account.

The relationship between coefficient of friction and relative sliding generally takes the form shown in figure III.1.*a.* where it will be seen that once the peak has been passed, an unstable condition exists which is inherently difficult to control. In adverse circumstances, the curve may take the form shown in figure III.1.*b.* which, whilst severely limiting the tractive effort which can be exerted, does enable a stable situation to be maintained.

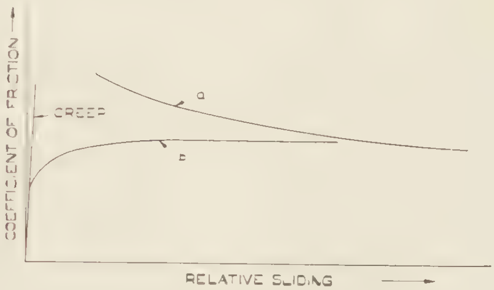


Fig. III.1. — Relationship between relative sliding and coefficient of friction.

Automatic devices are therefore employed which act on sliding taking place and this may be arranged to either 1) apply sand automatically to the wheel, 2) reduce tractive effort, or 3) modify the value of the load applied to the offending axle. The first problem is the detection of sliding by an instrument which is sufficiently sensitive to be effective but which is not affected by such factors as difference in wheel diameter or the normal acceleration of the train.

The most important aspect is therefore the means adopted for detecting the incidence of sliding. It will be recalled that with a series motor both current and the voltage across the armature change with speed. This fact may be used to indicate a sudden increase in speed accompanying sliding. When two motors are in series, a comparison of the voltages across their

individual terminals will also provide an indication.

Electric locomotives.

Seven administrations fit slip detection devices (in India only on A.C. locomotives). For 4 administrations who do not fit any devices, one administration fits separate ammeters to each motor, and slip is noted by the remaining 3 by observing noise, ammeter flickering and general driving experience.

Diesel electric locomotives.

Twelve administrations fit slip detection devices. In other cases separate ammeters are fitted. Few administrations rely on the driver to note the incidence of slipping by noise and vibration.

Method of slip detection.

The following table shows the relative extent to which different methods of slip comparison are made :

		No. of administration
Electric Locomotives (7 administrations)	Voltage Comparison	2 ½
	Current Comparison	2
	Voltage or Current Comparison	1
	Speed Comparison	1 ½

(the reason for the ½ is due to Japan fitting different systems according to A.C. or D.C. vehicles)

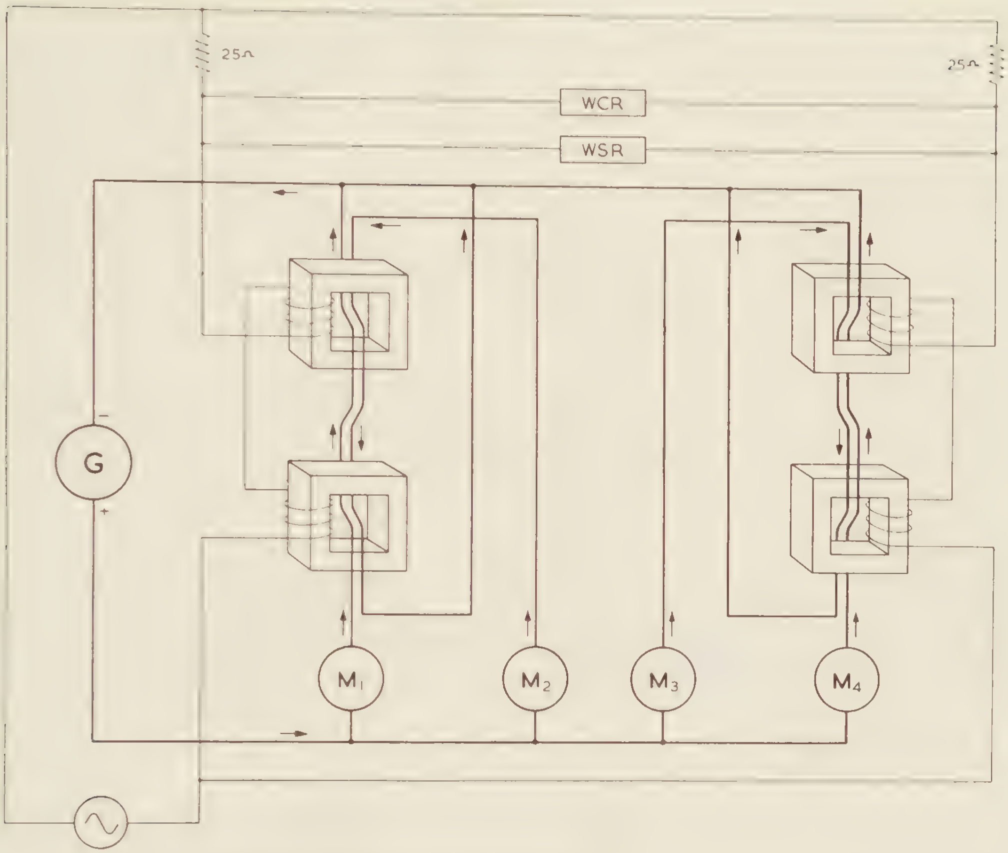
Diesel Electric Locomotives (12 administrations)	Voltage Comparison	3
	Current Comparison	4
	Voltage or Current Comparison	4
	Speed Comparison	1

An American manufacturer takes advantage of the fact that the modern Diesels have an A.C. supply for auxiliaries (2). This enables transductors (1) to be used. The motor leads carrying D.C. are arranged to pass through the transductor in opposition so that, when currents are equal, the A.C. winding is unaffected but, when a difference appears, the core approaches saturation with consequent effect on the magnitude of the A.C. current in the detection circuit. At starting, the two sets of motors are connected in series and wheel slip relays compare the voltage across each motor of a pair and the transductors compare the current taken by each group. Under moderate and high speed conditions, some adjustment of the sensitivity of the device is necessary to avoid false operation at low speeds but to maintain rapid action at high speeds. This is achieved by a third D.C. winding on the transductor which carries a current proportional to generator voltage. This also acts as an overspeed control.

Another company based its control system on the error signal arising from the output of one axle-driven generator and the average of all others. The setting of device has to allow for possible variations in tyre diameter. The present setting is tapered so as to operate at 6 m.p.h. speed difference at slow speeds to 12 m.p.h. at 100 m.p.h. This control has been successfully applied to the operation of the « anti-slip » brake (4).

The following modes of action have been reported :

Electric Locomotives (4 administrations) :



M_1, M_2, M_3 and M_4 = Traction motors;
G = Generator;
WCR = Wheel creep relay (operates sanding);
WSR = Wheel slip relay (reduces generator excitation);
(∼) = A.C. supply.

Fig. III.2. — Simplified circuit for inductor control.

Swedish Railways — Power Reduction.

T.G.O.J. — Power Reduction.

Japanese Railways — Power Reduction + Sanding.

British Railways — Power Reduction.

Diesel Electric Locomotives (12 administrations) :

New South Wales — (G.M.) Power Reduction + Sanding;
(Alco Power Reduction).

South Africa — *a*) Power Reduction + Sanding;
b) Power Reduction.

U.S.S.R. — *a*) Power Reduction;
b) Other experimental methods.

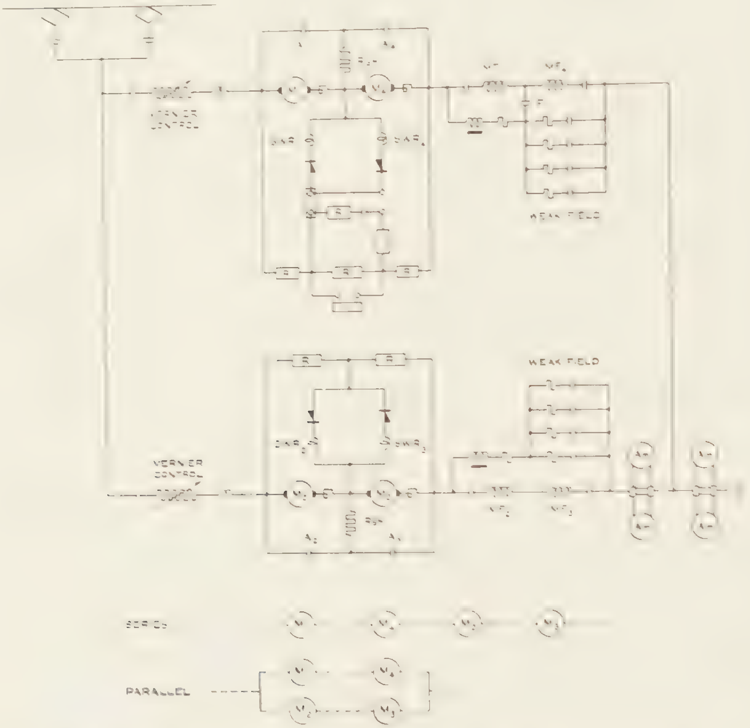
India — Power cut after serious slip.

Uruguay — Power Reduction.

Indonesia — Power Reduction + Sanding.

Ghana — Power Reduction + Sanding.

Japan — Power Reduction + Sanding.



The 2-axle bogie trucks; all axle drive (4 axles); traction motors M_1, M_2, M_3, and M_4;
M_1 and M_4 in the above figure are the traction motors to drive the axles fitted near the couplers;
MF = Traction motor field;
F = Weak field switch for compensation of shift of axle load;
A = Armature shunting switch;
Rsh = Armature shunting resistor;
SWR = Slip warning relay;
R = Resistor;
Am = Ammeter.

Fig. III.3. — Slip control of D.C. locomotive.

Sudan — Power Reduction + Sanding.

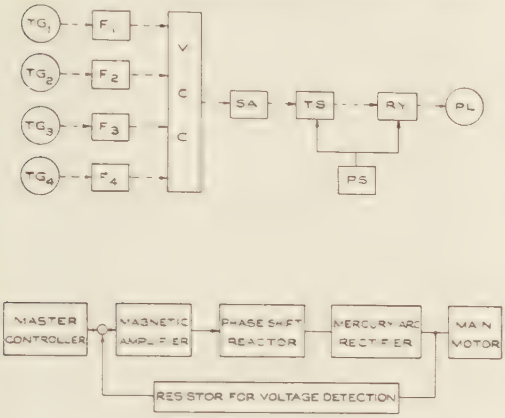
Sweden — Power Reduction.

New Zealand — (GM type G 12) Power Reduction + Sanding.

Nigeria — (GM) Power Reduction + Sanding.

It has often been noted that experienced drivers will sometimes correct a slip by a mild application of the brakes. This forms the basis of a device for anti-slip protection whereby air at a reduced pressure (about 0.8 Atm) is admitted to the brake cylinder when slip takes place (4).

Figure III.3. shown a typical control of a D.C. locomotive. The actual example chosen was provided by the Japanese National Railways. Slip is detected by comparison of motor voltages which causes operation of slip warning relays (SWR on diagram). The motors M_1 and M_4 are fitted with field weakening shunts which are operated to compensate for the shift in axle load. Switch F is arranged to weaken the field of the leading motor so as to minimise the risk of wheel slip. Terminal voltages M_1 - M_4 or M_2 - M_3 are compared and, on wheel slip occurring, SWR1 to 4 detects which motor has slipped. Then A_1 - A_4 operate to shunt field of slipping motor and to operate sanding.

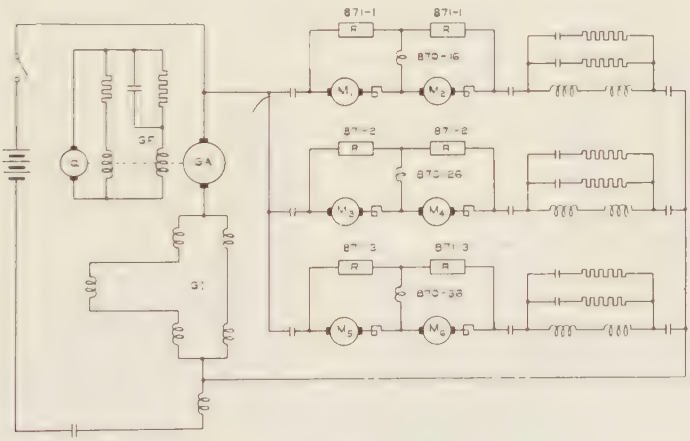


TG = Tacho generator;
F = Filter;
VCC = Voltage comparison circuit;
SA = Sensitivity control;
TS = Transistor switch;
RY = Slip relay;
PS = Power source;
PL = Pilot lamp.

Fig. III.4. — Slip control of A.C. locomotive.

Figure III.4. illustrates the principle applied to A.C. locomotives wherein the voltage applied to the motors may be made continuously variable and are fitted with an automatic detection device which keeps terminal voltage constant at the desired value by shifting the phase of the mercury arc rectifier. On wheel spin occurring, the consequential sudden change in motor current may be made to operate the control.

Figure III.5. shows an application to Diesel electric locomotives. Six traction motors



870 = Slip warning relay;
871 = Series resistor for slip warning relay;
M = Traction motor armature;
GA = Generator armature;
GI = Generator series field;
GF = Separately excited field;
Q = Exciter armature.

Fig. III.5. — Slip control of Diesel locomotive.

are connected with pairs of motors permanently in series to give three parallel circuits. The slip warning relays 870-16, 870-26 and 870-36 do not carry current as long as the voltage across motors M_1 - M_2, M_3 - M_4, M_5 - M_6 are in balance. On slip occurring on any of these motors, the relays operate to alter the setting of the engine governor and to insert resistance into the separate excitation field of the generator so as to reduce the voltage generated by the main generator.

For direct measurement of the amount of relative sliding, British Railways have used Magslip devices on trial. Musyck (15) has put forward the proposal that Selsyn devices might form the basis of a practical slip control system.

The answers to the question « What are the quantitative limits governing the sensitivity of the spin correcting device ? » are very few. The replies are listed below and refer to the Diesel electric vehicles :

U.S.S.R.	— Sensitivity 8 - 10 km/h.
T.G.O.J.	— Warning at 50 amps differential current.
Japan	— Detection down to 5 km/h.

The following limits to factors governing sensitivity are listed by the Japanese National Railways :

variation in wheel diameter .	1.5 % Max
variation in motor characteristics	3 % Max
unbalance in motor currents during starting	None

Separate devices for detecting the overspeeding of motors are seldom fitted, reliance being placed on anti-slip control.

The probability of failure of an anti-slip indication was not considered to be serious by most administrations and « fail safe » design, e.g. circuit fault indicates slip, was employed in only one case with electric locomotives and three cases with Diesel electric locomotives.

The majority of administrations who replied to the question stated that they had not experienced the circumstance of all axles slipping simultaneously when automatic spin detection devices were fitted.

Regarding the detection of wheel slow up, this is generally confined to multiple unit passenger equipment. In a few cases of locomotives, generally when dynamic braking was applied, the wheel spin detection device also acted as a « slow up » detection device.

The following administrations commented specifically on the advantages or otherwise of detecting wheel « slow-up » :

Japan	— Prevention of wheel flats - shorter braking distance.
New South Wales	— Warns driver of dangerous condition.
New Zealand	— Not warranted due to low maximum speed.
South Africa	— Cost not justified.
Sweden	— Useful in connection with disc brakes.
United Kingdom	— Prevention of wheel flats - shorter braking distance.
Uruguay	— Prevention of wheel flats.

SECTION IV. — TRANSMISSION OF SIGNAL INDICATIONS (CAB SIGNALLING). — VIGILANCE CONTROL DEVICES. — AUTOMATIC TRAIN STOPS.

Control of the spacing between trains is traditionally achieved by instructions to the drivers from wayside signals. The block system is now almost universal whereby signal indications are arranged so that no two trains can be in a section at a given time.

The correct observation of signals is so vital that many administrations have introduced automatic aids to signal observance by the driver (7). These systems may either be continuous, i.e. providing a constant indication in the driver's cab, or intermittent, i.e. indicating to him the position

of fixed signals when his train is about to pass them. A typical example of the former system as used in the U.S.A. is based on the coded track circuit. Here the track circuits are fed with A.C. which is pulsed at a rate of 180 pulses per minute for a clear indication, 120 pulses per minute for the « approach medium » indication, 75 pulses per minute for the « approach » indication, and of course no pulses for emergency stop. Considering a series of blocks, the first block would be shunted by a train and would have no pulse to the rear thereof, the next block would have 75 pulses — this would be translated by relays at the next block to 120 — and finally to 180 for the next block and all the way down the line. Coils placed on the locomotive sense these pulsations and provide cab signalling continuosly and it has recently been decided that this shall in fact operate the controls of the train.

An example of the intermittent system is the « Automatic Warning System » operated by British Railways. The track apparatus consists of two vertical magnets situated 200 yds. on the approach side of each distant signal. The first is a permanent magnet with south pole upwards. The second is an electromagnet, energised with north pole upwards but only if the distant signal is at « Clear ». When a locomotive, equipped with a suitable magnetic receiver, approaches a « Clear » distant signal, the influence of opposite poles in succession causes the locomotive apparatus to initiate the sounding of a bell for two seconds. When the signal is at « Caution », the receiver is influenced by the permanent magnet only, so that a horn is sounded and after a 3 second delay, a progressive brake application is applied which halts the train before reaching the home signal. The brake application may be prevented by operating the reset device in acknowledgment of the « Caution ». This also silences the horn.

It will be gathered that such systems can be used either to warn a driver that he has passed a danger signal or they can be arranged to initiate a brake application should he fail to take the necessary action.

Apart from the British and American efforts referred to only two out of fourteen administrations appear to be actively engaged in the study of these subjects to any marked extent. These are the J.N.R. and the U.S.S.R. These administrations use cab signalling extensively both of the continuous and intermittent type. For continuous signalling the track is excited at audio frequency to create a magnetic field which induces signals in a pick-up coil in the cab by electromagnetic induction. Information regarding the signal aspect is conveyed by pulsing of the magnetic field in coded form (U.S.S.R.). The Japanese system also employs magnetic coupling from track circuits excited at audio frequency but the information is conveyed by b.f. amplitude modulation of the a.f. carrier.

The intermittent system in both cases relies on electromagnetic coupling between tuned circuits on track and locomotive and is probably an adaptation of the Identra system (see Section IX).

Four administrations are equipped to use automatic train stop devices (U.S.S.R., J.N.R., N.S.W., N.Z.) and in most cases the brakes are operated. In particular, J.N.R. have developed a system capable of halting the train at a prescribed point. (This may be related to the apparatus described in Section VIII on Discontinuous Control.)

U.S.S.R. expects to eliminate the necessity of the motorman confirming observation of a signal and to exclude the possibility of passing a closed signal at high speed. Automatic control of decrease of speed of approach to a closed signal will be provided to permit safe approach to a minimum permissible distance, thus increasing utilisation of track.

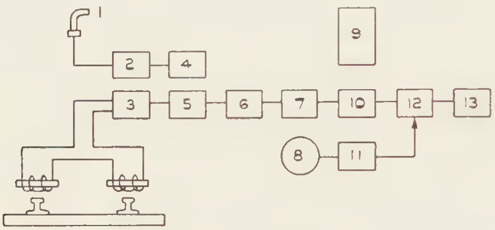
The abbreviated answers to questions 1-7 are given in Tables IV.1-5 (attached).

The J.N.R. intends to proceed with spot control system, except where continuous control is already fitted and requires extention to adjacent stations.

The New Tokaido Line will be conti-

nuous control. (This is the line chosen for fully automatic working.)

Regarding future policy, the U.S.S.R. state that where automatic blocking is the rule, continuous locomotive signalisation will always be used. All locomotives running on these sections are equipped regardless of type of train or maximum speed. The intention is to use automatic block system in all high traffic density areas.



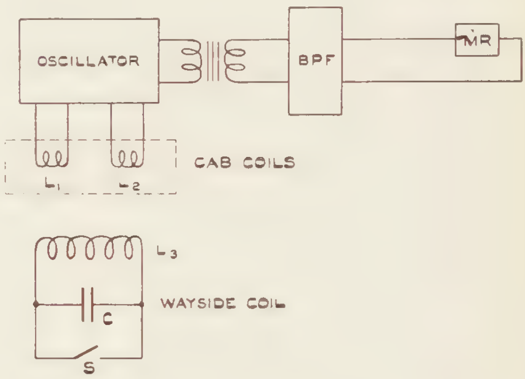
1. Electrostatic antenna;
2. Amplifier;
3. Band pass filter;
4. Frequency amplifier;
5. Balanced modulation;
6. Band pass filter;
7. Selective amplifier;
8. Tacho-generator;
9. Cab signal;
10. Control relay logical circuit;
11. Shapping circuit;
12. Logical circuit;
13. Brake controller.

Fig. IV.1. — Block diagram of continuous train control.

An improved system of traffic control is planned. It is hoped to eliminate the necessity of a motorman periodically confirming observation of signal by introducing equipment controlling train motion. Automatic control of decrease in speed of approach to a closed signal is to be introduced in an effort to increase line capacity by reducing the safe allowable distance.

Regarding detailed description of control circuits, the reply of the J.N.R. was most explicit and is summarised below :—

Figure IV.1. illustrates the scheme contemplated for use on the projected New Tokaido Line. Single sideband modulation of 720 and 900 c/s carriers by several low frequencies (10, 15, 25, 29, 36 and non-modulation) is fed into the track, the modulation frequency depending on designated speed. This signal is received by inductive



BPF = Band pass filter;
MR = Relay;
C = Capacitor;
S = Switch;
L = Inductor coil.

Fig. IV.2. — Block diagram of cab warning device of spot control type.

coupling and mixed with the unmodulated carriers (720 and 960 or 780 and 960 c/s) received by electrostatic antenna from wayside equipment, the resulting output being the frequency of modulation indicating the desired speed. This is compared with actual speed from an axle-mounted tachogenerator and braking control exercised, depending on the output from the logic circuit.

Figure IV.2. shows an example of frequency converting type. The wayside coil is resonated with coil, L_3, at 120 kc while on the cab coils, L_1 and L_2, are in loose coupling and constantly resonated at 100 kc to work the relay MR through band-pass filter. When the cab coil passes the wayside

coil, L_1, L_2 and L_3 compose a coupling circuit if the switch S is open, and the oscillation frequency changes from 100 to 120 kc, thereby cutting off the circuit current by band-pass filter to result in drop-away of MR. When S is closed the coupling circuit is not composed, so the oscillation of 100 kc does not change and therefore the contact of relay does not fall. Cab warning is sounded as the switch S opens when the signal displays « stop », while it closes when the signal displays « proceed ».

Figure IV.3. is a schematic explanation of receiving set of cab warning device in service on sections exclusively operated with electric multiple unit trains. On the ground an approach relay and time relay are added at the sending end of track circuit of commercial frequency, 50 or 60 cps. When a train reaches a spot a certain distance (brake distance plus allowance) before the signal displaying stop, the contact of the approach relay drops away to cut the power source and after a certain time resume feeding. The receiving set on the cab operates to induce the signal current of the track circuit (50 or 60 cps) to the cab through receiving coil; the relay, MR, which is

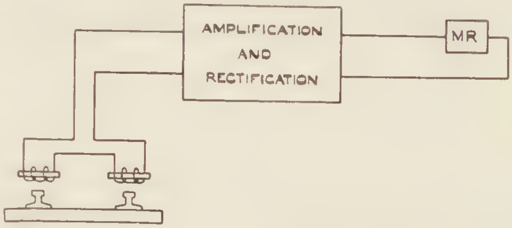


Fig. IV.3. — Block diagram of cab warning of approach relay type.

constantly excited makes drop-away, thereby sounding the cab warning, when the signal current on the track circuit is cut. The alarm keeps sounding to warn the driver till he takes action in acknowledgment.

TABLE IV.1.

QUESTION : 1) *Are any of your motive power units equipped with devices transmitting continuously or intermittently the position of the signals to the train? Which ones and according to what criteria are these chosen?*

If so, please state which signals and in which aspect and give sufficient information about your signalling system to enable the functioning of the train-borne equipment to be understood.

QUESTION : 2) *How does this transmission of signals reach the driver and are signal indications recorded automatically?*

J.N.R.

Continuous system displaying 3 aspects is used on important main lines. Intermittent 2 aspect is also used.
An amplitude modulated carrier signal (1.3 kc/s & 25-35 c/s mod.) flows in track circuit and through axle. Current through latter creates magnetic field which is detected by coil, amplified, processed according to modulation and used to initiate visual and audible warning.
Intermittent system uses wayside coil (Identra) coupling with cab coil. Electromagnetic coupling characteristic depends on signal aspect. Stop indication gives visual and audible warning to

U.S.S.R.

Generally, all locomotives are equipped for continuous cab signalling where automatic block signalling is used. On some sections, where there is no automatic block system, locomotives are partly equipped for intermittent control. (All new electric and Diesel locomotives are equipped with continuous system during construction). The link between track and locomotive is by magnetic field created by A.C. in rails and picked up by coil in locomotive. The A.C. is pulsed in a code corresponding to the aspect displayed; these impulses are decoded in the locomotive and coloured lamps are illuminated corresponding

J.N.R. (continued)

driver. In sections exclusively for m.u. electric trains, track circuit contains current at commercial frequency. As train approaches stop signal, increase of current due to train shunt is detected on ground. Current is cut causing contact of cab relay to drop and warning sounded. Signal aspect recorded with train speed in some cases.

U.S.S.R. (continued)

to the signal state. All aspects are displayed; if train passes closed signal (Y & R) the display is R. With intermittent control, decoder illuminates lamps in like manner except for the last. A system similar to Identra is used but with two resonant frequencies (1 kc/s and 1.4 kc/s). Both frequencies mean entry and exit open (green). First frequency only, means entry open, exit closed (yellow). Second frequency only, means entry closed. (No mention is made re. the absence of both signals).

TABLE IV.2.

QUESTION : 3) *Is the apparatus so adapted that the driver has to prove his vigilance by acknowledging the lineside signals before the transmitted signal reaches the train?*

J.N.R.

The driver confirms wayside signal and thereby allows train to proceed. Where recording speed meter is fitted, acknowledgment is shown.

U.S.S.R.

Reply states that the cab signal shows state of track signal up to the moment it becomes visible, continuously.
Intermittent system; cab lamp is extinguished 10-12 seconds and warns motorman of state of entry signal if invisible to him.

TABLE IV.3.

QUESTION : 4) *Are any of your motive power units equipped with automatic train stop devices?*

If so, are they connected with or separate from the signal transmission and/or vigilance systems referred to in Questions 1 to 3?

J.N.R.	*N.S.W.*	*N.Z.R.*	*T.G.O.J.*	*U.S.S.R.*
At present gives warning only, but motive power units are so constructed that the brake may easily be connected with the warning device. Successful field trials of automatic brake equipment capable of stopping train at prescribed point completed. (See description in Section VIII - this probably is equipment referred to).	Automatic train stop is fitted.	M.U. stock and electric and Diesel locomotives operating in areas covered by m.u. are fitted.	One electric locomotive fitted.	All locomotives equipped with automatic locomotive signalisation have automatic stops controlled by the system.

TABLE IV.4.

QUESTION : 5) *Does your automatic train stop act on traction control or on the brakes, or on both?*

J.N.R.	*N.S.W.*	*N.Z.R.*	*U.S.S.R.*
The current intention is to operate brake only but future developments envisage fully automatic train.	It acts on both, indirectly on traction.	It acts on both.	It acts on brake system only.

TABLE IV.5.

QUESTION : 6) *Does the brake application caused by the automatic train stop take the form of an emergency brake application to give a minimum braking distance though with possible surging of the train, or is the automatic braking pre-set in accordance with the load and composition of the train?*

QUESTION : 7) *What happens if your automatic train stop device has been set in motion when passing the warning signal, but the stop signal is cleared in the meantime?*

J.N.R.	*N.S.W.*	*N.Z.R.*	*U.S.S.R.*
A brake system to act on traction control is contemplated — working retarding force and maximum retarding force fixed for each speed range will be applied automatically according to signal indication.	It gives minimum braking distance.	It acts on emergency brake.	It acts on emergency brake.
Where brake handle is not operated by hand, emergency brake will stop train and cannot be released until train stops. In new system contemplated, automatic train stop releases as soon as signal change permits.	Action ceases.	Braking continues regardless of change in signal aspect.	

SECTION V.
DEADMAN'S DEVICES.

The assumption that the driver's function is to close an open loop control presupposes continuous vigilance on his part. Illness, sleep or even temporary inattention by him, therefore, may lead to a disastrous lack of control and a number of administrations have found it necessary to introduce automatic devices to safeguard against this situation. An important part of the question as to whether or not such devices should be installed depends on whether it is the practice to employ more than one man at the control station. This naturally varies with the type of motive power used, the type of traffic handled, economic and political situation in the country concerned.

Deadman control devices have been regularly fitted on multiple unit electrical equipments almost since these were first operated. The main purpose is to assure that the train is safe under the control of only one man.

The traditional arrangement is that the master controller handle is fitted either to spring up when released or a push button in the handle springs up. This causes the control circuit to be broken and the air brakes applied. The handle must be returned to the « off » position before it can

be depressed to release the brakes and power is not applied until the handle is again moved to an operating notch. Even with the handle in the « off » position the brake application is made if the handle is released. The emergency feature is out of action if the handle is in « off » and the reverse handle or key is moved to « off ». The most common abuse of this system is coasting with the reverser in neutral, or deliberate tying down of the handle in operating conditions, but on the shorter runs usually there was no reason for any such abuses.

The system has the following disadvantage : with the recent practice of providing the driver with a seat, there is the great possibility that if taken ill he will fall across the handle and prevent its operation. This has been overcome by the fitting of a pedal or treadle of a shape or position such that it will not be subject to this fault.

In some cases, it is necessary for the driver when alone to cross the cab to view a signal. For this, a treadle or a push button are provided and to cover the pause a time delay system is incorporated (usually pneumatic or vacuum). This time delay system also allows the power switch off to take place a little before the brake application, resulting in a more uniform stop. It is necessary on unfitted trains to make the application slower and a « passenger-freight » facility is usually provided.

A completely different scheme has been developed which is called intermittent as opposed to the previous one which requires the driver's continuous attention. In this scheme, the driver must make an action at maximum time intervals. This action can be performed with existing apparatus, e.g. moving controller back and forward one notch or moving the brake handle to release and back to running, or pressing and releasing a push button or treadle. All these motions are lumped together and if one is missed after an interval a buzzer blows and continues to do so until an action is made. Failing this, after a second interval the power is switched off and the brake appled. Where an axle driven speedometer and mileage counter is provided the interval is often measured on this and is related to a distance giving quicker action on passenger trains. This latter system is often known as a vigilance system.

From the replies all 16 railways fit some deadman protection on some stock :

- 6 railways fit deadman protection on all new electric and Diesel stock;
  all electric multiple units are fitted;
- 1 country does not report fitting it in shunters and Diesel railcars;
- 4 countries do not fit it on electric locomotives;
  all Diesel locomotives seem to be fitted;
- 6 countries report that their decision to fit or not is not affected by one man operations and
- 4 countries report that it is;
- 1 country reports that it fits it on electric locomotives although the Trade Union will not allow one man operation;
- 1 other country reports labour trouble on this score;
- 1 man operation is universal on electric and Diesel multiple units except on long runs, night working and single line operation;
- 10 administrations use 2 man operation although 6 of these have locomotives fitted with deadman protection;
- 1 administration is using locomotives with 1 man operation except for long runs and special difficulties;
- 16 railways use the continuous system;
- 1 uses the intermittent system;
- 1 has experimental units on intermittent system;
- 1 appears to use a different system where an emergency push button is used to cut power and apply brake.

All multiple unit equipments (electric and Diesel) operate trip immediately; those locomotives which are fitted trip after 5-8 seconds.

The one intermediate system reported 5-15 seconds between driver's actions and operation of brakes after 1 980 yards.

Japan reported the experimental use of 15 seconds and 200 m. 5 railways reported that duplicate pushes were fitted (all on locomotives).

No railway reported any special procedure to reset and all switched off (by reversing key) the scheme at standstill. No railway reported means of avoiding abuses but two reported strict supervision by travelling inspectors, one with severe disciplinary action.

On deadman failure most equipments are taken out of service, 5 operate when 2 men are available and 1 system (Sweden) operates below 40 km/h until a second man is available.

SECTION VI. — MULTIPLE-UNIT CONTROL OF SEVERAL COUPLED MOTIVE POWER UNITS FROM A SINGLE DRIVING CAB.

It is often the practice for motive power units to be required to operate together. The propulsion equipment for passenger trains is often arranged on a multiple unit basis, i.e. electric motors or Diesel engines are distributed over a number of axles throughout the train rather than being concentrated in a single locomotive at its head. Again, where this is not done, particularly in freight service, it is often necessary to employ more than one locomotive to propel a train. It is obviously uneconomic to provide a driver to control each motive power unit and even in circumstances where this is done, difficulties often arise from lack of co-ordination between the men concerned. It might be feasible to arrange for the energy required to supply all the motors to pass through a single controller but it has long been the practice to arrange for the basic control equipment to be provided for each motive power unit which is in turn commanded by a master controller.

Because of the need for carrying the control circuits from vehicle to vehicle, and because all vehicles to be controlled may not be of identical design, the basic control system is generally simple, the main control function being replicated on each motive power unit. In the case of locomotives, some indication is often provided in the driver's cab regarding the response of a second locomotive to his control action; this usually takes the form of an ammeter. In the case of multiple unit passenger stock, this is considered to be unnecessary.

To provide control of the unit or units control stations can be set up anywhere and the wires energised as required. These wires can be carried to all the equipment up to practical limits. Any number of these control stations can be set up, the only proviso being that all must be wired to a common multicore cable and only one must be operated at any one time. As few wires as possible are used and the traction function of electric motor coaches are usually done with 10 cores.

The greatest use of this arrangement has been in multiple unit electric coaches where one or more equipments are remote controlled on a unit and each unit equipped with a controller at each end. Any number of these can be coupled together and connected electrically by multicore jumper cables or automatic coupling. Trains are made up and split to suit traffic demands.

The same thing can be arranged for electric or Diesel electric locomotives to enable 1, 2 or more locomotives controlled by one man to pull trains of various sizes.

Coaching stock is sometimes marshalled in rakes and wired with the control lines from end to end. A locomotive is sometimes attached to both ends and sometimes to one end only (in this case the end of the coaching stock is equipped with a driver's control position). The advantage of this system is that the motive power can be released for other duties when not required. This system is known as the « push-pull » system.

Replies received indicate that all electric coaching stock and all Diesel railcars (except railbuses) are equipped for multiple unit control and driven from either end.

All Railways except two have their elec-

tric locomotives arranged for multiple unit control (British Railways do not and one administration did not answer. British Railways locomotives are sufficiently powerful to carry out any expected duty without assistance. Braking connections exist, however, so that an idle locomotive can be worked where required without the need for a second driver).

All railways operating Diesel electric have their locomotives equipped for multiple unit control.

Three out of four operating Diesel hydraulic locomotives have them equipped for multiple unit control.

Four railways use not more than two electric locomotives in multiple but two of these use more than two Diesel electrics when required.

Two railways have locomotives equipped with multiple unit but do not use the facility.

No railway drives from any position except in the front of the train except in emergency.

In emergency, some railways permit driving from a cab in rear but either assistant driver or guard is posted in front to relay signals to the driver and to apply the brake in emergency. Under these conditions, speeds are restricted to 10-30 m.p.h. and some specify « slow ». Four railways allow this only to the nearest station.

Three railways do not permit driving from any cab other than the front one. Presumably in emergency these drivers must summon other assistance.

In all cases the methods of multiple unit control are those described above.

One railway uses an air pipe pressure to operate remote control on its Diesel locomotives.

To check that all remote controlled equipments are functioning correctly, most railways operating electrical equipment have an indicator light in the leading cab to check that all the line switches have operated.

Several railways do a control sequence check when trains are coupled up.

One railway (Sweden) provides no means of checking other equipment. One railway (Japan) provides an ammeter indicating the amps in the remote unit (useful for double headed locomotive trains only).

On modern electric locomotives, it is becoming customary to provide indications of several malfunctions. (This involves many more train line wires and applies to two units coupled only.)

One railway indicates : blowers, wheel spin, control cam shaft, transformer oil, overload.

One railway indicates : traction overload and motor generator sets.

On Diesel locomotives, more functions are indicated and as more than two units can be involved, many more wires are required.

The following are such functions generally indicated : wheel spin, engine shut down, hot engine oil, engine overspeed, low lubrication oil level, battery charge condition, steam heating, dynamic braking.

In addition, three railways report that it is the assistant driver's duty to visit the other units at regular intervals on a journey to check that all apparatus functions correctly.

For fire alarm, seven administrations report no alarm system, two report a bell system and two report an indicator system. (Those with alarm systems are generally Diesel locomotive operators.)

SECTION VII. — REMOTE CONTROL OF SHUNTING LOCOMOTIVES.

It will be seen that when automatic acceleration and braking are provided, the control actions required by the driver are relatively simple and could, where necessary, be transmitted from a point away from the locomotive by an automatic link. This would have some advantages and has been employed in the following situations :

1) where it is desired to control the speed

of a shunting locomotive in a hump yard from the same control point as are the sorting movements, e.g. points and retarders;

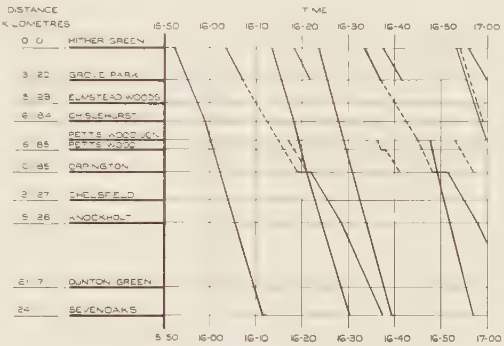
2) in yards such as those associated with steel works where movements have to be related to the action of other equipment. A well-known example is the loading of coal and over-burden spoil in large open cast mines where the operator responsible for the conveyor which brings the material forward for loading is able to control the speed of the train so that it moves forward under the delivery end of the conveyor at the speed appropriate to uniform loading;

3) another instance of the use of radio is in connection with assisting engines marshalled into a train at a point remote from the main engine so that they can be operated in unison therewith.

SECTION VIII. — AUTOMATIC OPERATIONS OF TRAINS.

It will have been gathered that the elements of a control system which would operate without the agency of a driver already exist. A system operated solely on the basis of signal operations would, however, lack the flexibility required under normal traffic conditions.

A completely automated railway will require to embody a kinetic control system, i.e. a control system the purpose of which is to control the displacement or the velocity or the acceleration or any higher time-derivative of the position of the controlled member. The easiest way of representing the desired pattern of behaviour is the graphical timetable such as illustrated in figure VIII.1. It is usual to prepare such diagrams using straight lines to represent the distance/time relationship of individual trains. This would employ infinite acceleration and deceleration and constant speed. The diagrams should therefore be modified to allow for the finite values of acceleration and deceleration and the economic speed. For the purpose of this discussion, however, it will be sufficient to regard the graphical timetable as an instruction given to the railway system and the function of the control apparatus is to operate the service in as close conformity with this diagram as possible. As indicated earlier, reliance could be placed on the block system in association with automatic train stops, to maintain a safe value of separation of trains. The signals themselves could be operated from a central point by computer in order to determine the starting time and stopping position of each train movement.



Key : Hither Green to Orpington.
Fast line ———
Slow line - - - - -

Fig. VIII.1. — Example of graphical timetable.

Whilst this is a feasible system, it could only be satisfactory where the speed's characteristics and stopping distances of succeeding trains followed a very uniform pattern which had been taken fully into account in the design of railway signalling and rolling stock.

In order for a smoothly acting control system to operate, it should be continuous rather than governed by the incidence of signal checks and this involves some form of communication between the control and the motive power unit and some stored information of the unit itself. At one extreme, the speed both during the traction and braking operations would be determined by a signal fed to the locomotive. The other extreme, a simple starting instruction would be given to the loco-

motive and the speed/time relationship to be followed would be governed by some memory element stored within the locomotive.

There is considerable scope for study as to what is the correct control philosophy to be applied to an automatic railway (9) (14). The answers to the questions confirm the impression given already in Section IV, viz., only two of the administrations who have replied fully to the questionnaire (J.N.R. and U.S.S.R.) have made significant progress in the application of automatic techniques for the control of train movements. The Ministry of Transport of the U.S.S.R. reports experiments on a system which is devised primarily not to replace footplate men but to enable them to drive the train even more economically (17).

This system is based on a computer situated on the motive power unit. In addition, however, to the stimuli received from the road being fed to this computer, prepared information regarding timetable and traction characteristics is stored therein.

The sequence of operations is as follows : the train is started by the motorman pressing a knob and gathers speed under the control of an acceleration relay. During the acceleration, the computer works out the time at which the train will arrive at the destination, and will select the control characteristic to give minimum energy consumption. Stopping of the train in stations is determined by the programme and brakes are applied automatically. The progress made by the train is measured upon the axle and compared with the predicted position. If the difference between calculated and programme time ($\gamma_0 - \gamma_1$) at any point is positive, i.e. if the train is late, then another traction characteristic is automatically selected to give more power. If the difference is negative, a lower characteristic is selected or the train is allowed to coast. Thus allowance is made for the variation in train load or in train resistance due, for example, to weather conditions.

Stopping or restricting signals from the automatic block system are fed to the locomotive and the brakes applied accordingly. Four stages of braking intensity are employed and the error in position of stopping does not exceed 20 m. The effect of signal checks is of course taken into account by the computer in determining the subsequent stages of the journey. In addition to the transmission of signal indications by induction through the rail, check indications of position are provided by radioactive elements fixed relative to the track.

J.N.R. do not as yet run an automatic train but they intend to do so and have nearly made a decision on the method to be adopted. This will take the form of control of acceleration and retardation of trains based on the results of calculations made by a central computer receiving information regarding position, speed and other relevant factors.

It would appear also from the replies that in addition to the above type of control, a programming method is under study. It is not clear whether the two systems are intended to be compatible and complementary. Seven speed ranges are contemplated, 210 km/h - 30 km/h, non-block and stop. The train speed will be automatically decreased according to signal. A movable block system will be examined, in which case the train speed will be controlled depending on movements of the preceding train. It is not stated by which means communication between trains is achieved, whether direct or through central control. At present track circuits with inductive coupling to locomotives are used to pass information but other methods, including wave guide, inductive radio and high frequency radio, are to be examined. The means by which the central computer receives position and speed are not indicated in the replies.

The automatic equipment is designed to « fail-safe », i.e. the train stops if any portion of the equipment fails to operate properly. Manual operation is possible if reserve equipment also fails. The abbreviated answers are shown in Tables VIII.1-6.

Some indications of future intentions of

manufacturers and operators in the United States regarding automatic operation of trains may be gleaned from a study of papers presented at the A.I.E.E. Railroad Computer and Automation Conference held at Cleveland, Ohio on the 6th and 7th June, 1961, and from other sources.

A paper presented by L. R. ALLISON of the General Railway Signal Co. describes the first successful remote control operation of a train from New Rochell, N.Y. to Rye, N.Y. in December 1955. In this case, commands to operate throttle and brakes were communicated using a 94 kc/s inductive carrier system, the control position being at Larchmont, N.Y. The author describes a number of ways in which information may be comunicated to trains, none of them being particularly novel. Automatic operation of a railway is not dealt with to any great extent but the author appears to consider that only information necessary to check position to the nearest block is required to be transmitted to the controller for check purposes, provided the train is fully automatic.

This view does not appear to be supported by another author (Franklin GEORGE, also of the General Railway Signal Company) who, in a lecture given on 19th April, 1961, to the American Transit Association, envisaged a railway system being supervised by a central control which would not initiate general running commands but would look at the whole system continuously. The aim would be to prevent a disorderly or abnormal condition arising in any particular area and provide re-routing information to other areas so that the situation would not worsen. Local areas would then have the responsibility of issuing detailed instructions, e.g. controlling acceleration, retardation or speed to obtain the best operating conditions possible in the circumstances.

The author discusses methods by which commands may be communicated to trains and suggests that the information may be fed into the track circuit, in coded carrier form, when the train addressed occupies the section into which the energy is fed. This would ensure that, because the train shunts the track circuit, trains to the rear would not receive the message causing them to act erroneously. Recommendations made by the author include (*a*) retention of at least one railway employee on the automatic train, (*b*) provision of a two-way voice communication system between the operator and the supervisory control centre and (*c*) provision of means by which the operator is enabled to control train propulsion at a low speed, say 5 m.p.h. when authorised by control. This would ensure that passengers would not be stranded in an undesirable situation and other advantages are apparent.

A report issued by the General Railway Signal Co., New York, « Automatic Train Operation — Carol Lake Railway » (1960) quotes the conclusions reached by Canadian National Railways on their consideration of the problem of automation. These show that continuous, not intermittent control, is preferred and that communication with the locomotive should be by induction from the track circuit (in code). This is to ensure that trains may receive commands at specific places and also generally to protect against false operation. It is apparently considered that radio or lineside induction techniques would be unsatisfactory in this respect. It is further claimed that track circuits would provide continuous control and cab signalling (although it is not clear why the other methods rejected would not also be suitable). A central « brain » is suggested for directing movements so that the role of the locomotive is that of a slave, thereby saving on equipment. No « intelligence » equipment would be necessary on the locomotive, except for that necessary to monitor behaviour and interpret commands. The system of control should be such that conventional trains would be capable of operation through the system, interspersed with A.T.O. trains.

A paper of considerable interest was presented to the Conference by John L. GABLE of the Chicago, Milwaukee, St. Paul and Pacific Railroad Co. This deals with the possibility of using a digital computer to

make decisions normally associated with human beings, e.g. the decisions made by a train dispatcher controlling distances up to say 250 miles using centralised traffic control. The paper (entitled « Heuristic Train Dispatching ») draws a similarity between the problems of train dispatching and games of skill, e.g. chess, and underlines how one decision will ultimately determine the shape of future decisions. The author showns how the depth of search in making the first decision is greatly influenced by the number of trains to be considered and the separations. If few trains are involved and they are separated by relatively great distances, then it is obvious that little effort is required to progress each train through the system. Conversely, a large number of trains more closely packed would require considerable thought to ensure the best possible operating instructions are made to avoid conflict since the movements of all trains become interdependent. The author suggests the use of a digital computer to simulate movements of trains (single line working is considered in the paper), projecting the movements ahead by discrete intervals of time and examining the effects of decisions. Since, at any particular instant of time, a large number of possible choices for future action exist, evaluation criteria are considered in the paper to discriminate between the various courses of action and to ensure that a « meet » takes place at an unoccupied siding which would cause least delay or produce the best system performance. The techniques suggested appear to be applicable to a railway system in general as distinct from the single line control discussed in the paper.

British Railways consider that the essential prerequisites for any such system is a reliable means for detection not only of the presence but the precise location of a train or obstruction together with a reliable and economic means for communication of control signals between the train and a central point. Research on these topics is proceeding in conjunction with the manufacturing industry.

Eventually, some system of adaptive control, designed to optimise the performance of the whole system, might be expected to provide important economic benefits.

Discontinuous control.

An interesting application of discontinuous control techniques has recently been developed by J.N.R. to provide automatic braking of rapid transit electric trains and to achieve an accurate stopping position at stations (13).

The system uses a family of curves relating velocity to distance from a datum point to the chosen stopping point (a total of 240 m in the experiment described). The curves are parabolic trajectories, each curve corresponding to a different braking force.

As the vehicle approaches the datum point at which control is to commence, full braking force is applied; this, if continued, would of course stop the vehicle before the desired position and the force must therefore be reduced to approach a more realistic value, commencing at the datum. This position is automatically identified by an Identra system (described in Section IX) but in this case the tuned coil is in the track, the control equipment being train borne. Operation of the Identra sets in motion an electromechanical function generator consisting of a motor driven computing potentiometer which is graded to provide an output corresponding to the desired velocity when fed at a voltage associated with a given braking force. The shaft position corresponds to distance run from the datum and is controlled from a car axle pulse generator. The potentiometer output is compared with the velocity signal from a tachogenerator coupled to an axle, the difference being proportional to the error between actual speed and desired speed. When the error signal indicates that true speed is less than desired speed, the control system notches to a reduced braking force and simultaneously switches the potentiometer supply voltage to a reduced value corresponding to the new tra-

jectory. The true speed is now greater than that demanded by the trajectory and this continues until both trajectories meet and eventually the true speed falls below the chosen trajectory, the cycle of operation being then repeated, i.e. the braking force is again weakened and a new trajectory chosen.

Experimental runs with a 50 t car, 20 m in length have shown stopping accuracies of ± 10 cm. Further work is in hand to improve the system.

TABLE VIII.1.

QUESTION : 1) *Do you envisage the possibility of automatic operation of railways? If you have such an installation in existence or under development, please answer the following questions.*

J.N.R.	*T.G.O.J.*	*U.S.S.R.*
Yes, not yet completed but laboratory and manufacturing tests in progress and final design details almost decided.	Yes	Yes, « automatic motorman » devised for suburban and metropolitan electric trains. Development of system for passenger Diesel locomotives commenced.

TABLE VIII.2.

QUESTION : 2) *How is the sequence of operations initiated?*

J.N.R.	*U.S.S.R.*
Position, speed and other particulars of train fed to central computer which calculates designated speed of each train and based on results of calculation, commands are passed back to trains to control power driving and braking.	Train started by motorman pressing button. Acceleration is controlled, during which time computer calculates time to reach end of control section. Automatic selection of traction characteristic is provided depending on whether train is ahead or behind programmed time.

TABLE VIII.3.

QUESTION : 4) *How is the information, regarding the state of the road ahead, transmitted to the locomotive :*

a) *by radio?*

b) *by induction through the rails?*

QUESTION : 5) *Is the control of speed realised continuously or by selection of a limited range of speeds?*

QUESTION : 6) *How is train speed controlled?*

J.N.R.	*U.S.S.R.*
At present by induction from track circuit to cab. But to improve system other methods, e.g. wave guide, G-line, inductive radio, etc. Reply refers to automatic braking apparatus using function generator (see description of discontinuous control in this section).	Through track circuit and locomotive signalisation system. Radioactive elements also used for check purposes at limits of control section. Speed control is over whole range. On sections of constant speed, upper and lower limits given. Driving characteristic chosen by

J.N.R. (continued)	*U.S.S.R. (continued)*
Seven speed ranges possible and programming method being studied. Time differences between actual and programmed run will be compared and programme automatically modified if necessary.	comparing real and programmed velocities. On time-controlled sections, speed may be permissible maximum. Equation of motion is solved to determine which characteristic should be chosen to keep speed below limiting value. On restricted sections, two steps of weaker braking characteristics used.

TABLE VIII.4.

QUESTION : 7) *How is the train brought to rest at signals?*

J.N.R.	*U.S.S.R.*
Method to be adopted for New Tokaido Line causes train to be halted by speed control signal 210-160-30 km/h (at intermediate signals). At stations, speed control is 210-160-70-30 km/h. See also description of discontinuous control in this section for station halts.	Predicted by programme and red automatic block signal. Four braking forces can be selected, the number of consecutive steps depending on initial speeds. Stopping error better than 20 m.

TABLE VIII.5.

QUESTION : 8) *How is the train brought to rest at stations or at other pre-determined stopping places?*

J.N.R.	*U.S.S.R.*
In the New Tokaido Line, by automatic control at speeds up to 30 km/h and manually at speeds in excess of 30 km/h. The device previously referred to — discontinuous braking control will be brought into service as soon as possible.	See answer to 7), Table VIII.4.

TABLE VIII.6.

QUESTION : 9) *What precautions are provided, in the event of failure of the equipment?*

J.N.R.

The automatic equipment fails safe and train stops. Manual operation is possible if reserve equipment also fails.

SECTION IX. — OTHER APPLICATIONS OF AUTOMATION TECHNIQUE.

It will be realised that in addition to the basic functions described in Section I, namely the control of movement, other functions occasionally have to be performed which are subject to automation. Two instances of this have been reported, firstly the control of electric power where it is desirable that this should not be attempted to be drawn over a neutral section. The automatic power control of British Rail-

ways is a case in point and it operates as follows :

the approach to a neutral section is sensed by a magnetic receiver within the locomotive which is excited by a permanent magnet laid on the track at an appropriate distance ahead of the neutral section. This magnet is identical with that used for the Automatic Warning System described in Section VIII but is mounted outside the rails rather than on the centre line of the track as in that case. The presence of the magnet causes a relay to operate the trip mechanism of the circuit breaker, the relay being immediately reset for the next operation. After exit from the neutral section, a similar magnet influences the relay to close the circuit breaker, the relay again being reset for further duty. Before the circuit breaker recloses, the system voltage is measured and appropriate transformer tape selected for 6 kV or 25 kV operation. If no voltage is indicated, the circuit breaker is prevented from closing; the same mechanism also acts as a « no volt » release.

Both magnets are laid at identical distances either side of the neutral section, thus permitting traffic movements in either direction.

Another instance is in the introduction of the route required by a train which may or may not be associated with automatic route setting. The Identra system (3) is basically composed of two parts, one of which is train borne and the other sited at a selected wayside position. The train equipment, usually mounted at a forward corner position of the motive power unit consists of a detachable tuned circuit (inductor and capacitor), the resonant frequency of which may or may not be variable. The chosen frequency is unique so that trains so equipped are endowed with individual « character ». The inductor is arranged to couple with a pair of coils in the wayside equipment thus causing an oscillation to be generated in the latter at a frequency determined by the tuned circuit mounted on the locomotive. Selective networks ensure that the rectified signal is used to operate controls or provide information necessary for the subsequent movements of the train. Destination of an approaching train, automatic announcing and automatic route selection are typical examples. It should be noted that the train borne equipment is entirely passive and therefore is inherently very reliable. Operating frequencies of the system are of the order of 100 kc/s.

Only J.N.R. appear to be active in other automation directions. Their intention to develop a fully automatic railway in which a central dispatcher will operate the whole network according to a programme has already been noted. This initiates the operation of points and signals at stations according to programme. An additional feature to be provided ensures that should the system get into disorder a data processing machine looks at the problem and revises the programme, new instructions being automatically issued to trains and stations.

The Identra system (described above) is used by J.N.R. to distinguish between electric railcars and trains hauled by locomotive. The signal aspects are changed to be suitable for the type of train and this increases utilisation. The Identra system is also being considered for automatic route selection and stopping (see Section IV on discontinuous control of braking).

As regards automatic power control, J.N.R. have developed experimentally for a test line automatic changeover between A.C. and D.C. The intention is to use ground apparatus to effect automatic changeover in the New Tokaido Line.

The travelling block system is also being studied.

SECTION X. — APPLICATION OF ELECTRONIC METHODS ON CIRCUITS OTHER THAN POWER CIRCUITS APPLICATION OF ELECTRONIC METHODS ON POWER CIRCUITS.

It will be clear that whilst the principles of automatic control can be applied by means of mechanical, pneumatic or hydrau-

lic devices, the main tendency is to use electronic devices for a major part of the system. The reason is that where only a message or instruction has to be conveyed, electronic means are the fastest and usually the cheapest. Where, however, the instruction has to be transformed into a force, pneumatic or hydraulic devices may be more effective for the final stage. Thus, in the control of Diesel engines, a pneumatic link is often provided in association with the engine governor.

Of the 16 replies received from the different administrations only four make use of electronics, either on trial or as standard equipment.

The U.S.S.R. use transductors (1) (12) with germanium rectifiers (18) for automatic control of exciters on Diesel-electrics.

South African Railways use silicon transistor control for transition on a limited number of Diesel-electrics, being manufacturers of standard equipment.

The Japanese National Railways use electronic and allied equipment extensively. Valves are used for the amplifiers in cab warning signal equipment and pantograph voltage detection equipment, and also in the speed recorder, but they are being replaced by transistors. Transistors are used in slip detection and in an automatic battery charger. Magnetic amplifiers are used in an automatic voltage regulator, an MG voltage regulator and a notch following device.

In power circuits, silicon rectifiers are used for conversion on some A.C. motive power units, and magnetic amplifiers are used for the control of field current of electric railcars equipped with regenerative braking. Germanium is not used in power circuits, but is used in control and detection. Elaborate precautions are taken to protect the silicon power rectifiers from current overload, overvoltage, and overheating. Programmed control of motive power is envisaged including an automatic master controller.

British Railways use electronic and applied devices to an increasing extent. Transductors are used for controlled battery charging and semiconductor rectifiers for mercury arc ignition and excitation, in many A.C. motive power units. Germanium and silicon rectifiers are being used as standard equipment for power conversion on some A.C. units and transductors are being used in power control circuits on a trial basis.

The controlled silicon rectifier (5) is applicable both for control and for inversion from D.C. to A.C. British Railways, in association with contractors, have more than one application under active development.

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[625 .14]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

18th SESSION (MUNICH, 1962).

QUESTION 1.

Adaptation of the methods of laying, aligning and maintaining the permanent way to carry traffic at very high speeds (120 km/h and more) :

a) on the straight;

b) on curves;

so far as they affect safety and taking into account the type of rolling stock used.

REPORT

(America (North and South), Australia, Burma, Ceylon, Egypt, Finland, Ghana, India, Indonesia, Iraq, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, Philippines, South Africa, Sudan, Sweden, Union of Socialist Soviet Republics, United Kingdom of Great Britain and Northern Ireland and dependent overseas territories),

by Kentaro MATSUBARA,

Deputy Director, New Tokaido Line General Department, Japanese National Railways.

FOREWORD.

The present questionaire was sent to 38 countries and the answers thereto have been so far received from 36 countries. There are not so many countries that submitted concrete answer, partly because the questionnaire contained a special condition i.e. « operation at very high speeds (120 km/h and more) ».

The present report is a summary of the concrete answers received from the following Railways :

Victoria Government Railways (Australian Rys), Railway Division of British Transport Commission (British Rys), The Chesapeake and Ohio Railway Company (C & O Rys), Egyptian Republic Railways (Egyptian Rys), Finnish State Railways (Finnish Rys), Indian Railway Board of Ministry of Railways (Indian Rys), Irish Transport Company (Irish Rys), Japanese National Railways (Japanese Rys), Chicago Rock Island and Pacific Railroad Company (Rock Island Rys), Seaboard Air Line Railroad Company (Seaboard Rys), Union of Socialist Soviet Republics Railways (Soviet Rys), Swedish State Railways (Swedish Rys), and The Texas and Pacific Railway Company (T & P Rys).

A speed ranging from 120-150 km/h which is now in practice in various countries is called « high speed » and the speed higher than that is termed as « super-high speed », in the present report.

The questionnaire is divided into the following five chapters :

1) Various information;
2) Layout of the line;
3) Constitution of the permanent way;
4) Renewal of the permanent way;
5) Maintenance method.

As for the information submitted by the Japanese Rys, it pertains to the experience with the narrow gauge lines and in addition the New Tokaido Line which is of the standard gauge and now under construction and for which the operation at a super-high speed of 200 km/h is expected.

1. Various information.

11. *Statistical data.*

Please fill up the annexed Tables Nos. 111, 112, 113 and 114 and join a map of your railway systems bringing forward the lines in question.

Please refer to the Tables 111-114 at the end of this report.

12. *Determination of the running conditions of locomotives and rail motor coaches.*

121. *Are the speed limits for locomotives and motor coaches on a given line assessed after trials, with direct measurement of the transversal thrust or measurement of the transversal accelerations and calculation of the stresses? Please give in an appendix any useful data available on this point.*

Inasmuch as the technique of measuring the stress, acceleration, etc. has recently advanced, the speed limits for locomotives and motor coaches on a given line are assessed after trials in many countries.

As the measuring items for the increase of speed on the high-speed section in the Japanese Rys, the following may be mentioned : the measurement of the wheel load and the transversal thrust (electric wire strain gauges are attached to the wheel spokes and from their strain the transversal thrust is obtained), the vertical and lateral accelerations of car body (accelerometers are installed at the bogie centre on the car floor), the riding quality of car body (riding quality gauges are installed on either the car floor or passenger seat) and the deflections of bogie spring and the deviations of swing bolster (electric measuring instruments are used). The measuring of these items is all carried out on the car. On the other hand lateral thrust and wheel load that the rail receives and the accelerations of the sleeper and ballast are measured on the ground, utilizing the wire strain gauge. On the basis of the results of these measurements the safety regarding the following items is examined.

1) As to the derailment due to the wheel riding on the rail, it is examined under the condition that the actually measured value of $\frac{\text{transversal thrust}}{\text{wheel load}}$ is 0.8 or less (see Answer 122).

2) As to the riding quality, the Janeway limit is taken as the coefficient of riding quality for the vertical vibration and the limit established by the Railway Technical Research Institute of Japanese Rys, as that for the lateral vibration, and in case of high-speed rolling stock those coefficients are set at 2 or less as shown in figure 121.

3) The limits of deflections of bogie spring and deviation of swing bolster are examined for each type of car and those of the accelerations of sleeper and ballast are examined for each type of track structure.

122. *What is the maximum transversal thrust allowed as a function of the axle load ?*

There are many countries where the maximum transversal thrust is specified as a

function of the axle load in consideration of derailment due to the wheel riding on the rail at the time of high-speed running.

Letting W denote the axle load and Q, the transversal thrust, Egyptian Rys specify the limit as Q/W = 0.2-0.3, and Indian Rys, Q = 0.4 W + 2.03 (ton). C & O Rys limit may be made higher and as to its extent the value shown in figure 122 is practised. The point of discontinuity at 0.7 m shows the distance estimated necessary for the wheel riding on the rail, which approximately corresponds to a quarter of the circumference of the wheel.

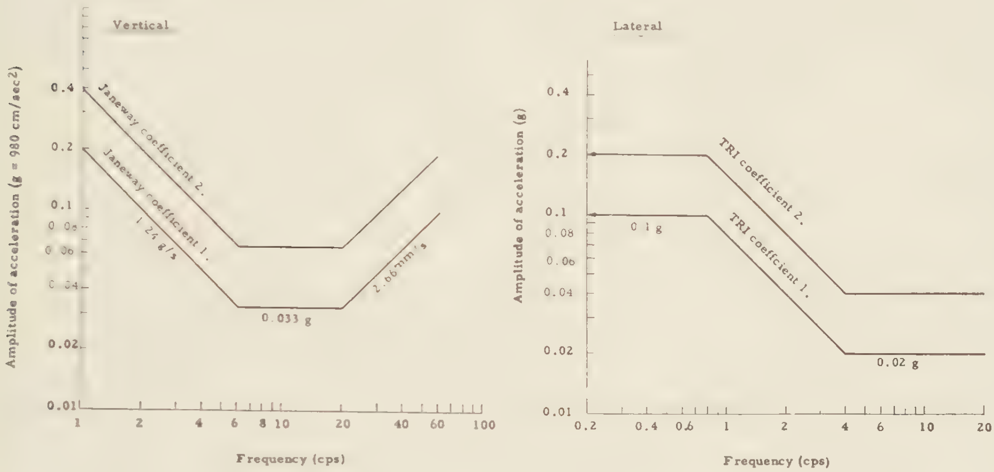


Fig. 121. — Riding quality coefficient.

has studied and calculated the derailing limit due to the wheel riding on the rail in the case the wheel of 762 mm in diameter hits the rail at various angles, assuming the inclination angle of wheel flange and the cœfficient of friction between the wheel and the rail as 63° 25' and 0.25 respectively. As a result the C & O Rys states that the limit of Q/P is 0.804, where P is wheel load and Q is transversal thrust.

The Japanese Rys, too, has calculated Q/P on the same principle, assuming the angle of wheel flange and the cœfficient of friction between the wheel and rail as 60° and 0.3 respectively, and obtained a value of 0.94. However, in actuality it adopts 0.8 instead of 0.94 for the sake of safety. Even if the transversal thrust is so big as to exceed the limit, the wheel does not ride on the rail so long as the tranversal thrust acts only for a short time, and therefore this

123. *What types of engines do you consider as having particularly harmful effects upon the track? For what reasons? Give diagrams showing, if possible, the causes thereof.*

The harmful effects upon the track caused by engines largely depend on the components of engine construction and therefore it is difficult to classify them by their types. Both British Rys and Indian Rys state that the electric locomotive and the Diesel-electric locomotive with axle hung motors have an effect more harmful than the steam locomotives does. Irish Rys states that the Diesel-electric locomotives appear to affect alignment and side cutting of rails to a greater extent than the steam locomotives, and Egyptian Rys states that the electric locomotive is bad in respect of the surface wear of rail.

In Japanese Rys the recent data concerning the engines are not available, because the high speed trains are to be composed of either electric or Diesel multiple-unit railcars. However, in certain past examples it was recognized that the electric locomotive of 2-axle bogie type gave smaller transversal thrust than that of 3-axle bogie type did and the locomotive of the type that its entire weight rests solely on the side bearers gave a large transversal thrust.

1) Swedish Rys carried out running trials at a speed ranging from 120 km/h to 130 km/h on a section on which the normal highest speed was specified at 100 km/h, in order to test the vehicles for high speeds and measured the transveral thrust and the acceleration in the driving compartments. The accounts and analysis thereof will be described in the Answers 132 and 133. For the track in this case 20 m rails were used and maintained in ordinary way, and it was found that misalignment of 27 m in wave length existed continuously. The trial train consisted of a locomotive and a recording-coach;

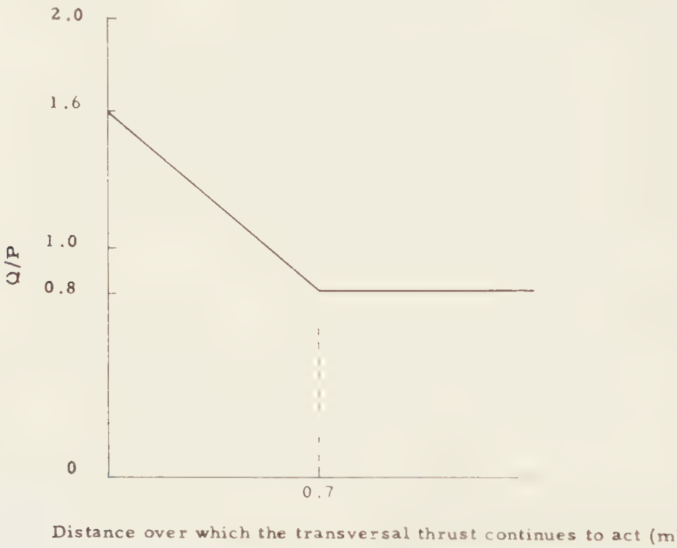


Fig. 122. — Limit of Q P.

13. *Results of running trials.*

131. *If you have carried out running trials at higher speeds than those normally allowed, please explain their purpose and the results obtained, giving all useful data concerning the constitution of the permanent way, its condition of maintenance, and the composition of the trial train.*

In order to ascertain the possibility of further increase of the speeds normally allowed, most countries conduct the running trials at higher speeds and the following is their brief summary :

2) C & O Rys carried out a running trial with the experimental train X equipment at a speed of 165 km/h for the purpose of testing the suspension of this passenger equipment. In this case the track was maintained in the ordinary condition and at the curved track a speed 30 % higher than that of ordinary coaches was developed;

3) Indian Rys carried out running trials at a speed of 113 km/h against the normal speed of 105 km/h, using a vestibuled and

TABLE 131-1. — **Running trial of Japanese Rys.**

	Unit	*Example 1*	*Example 2*
A Maximum speed	km/h	163	175
B Factor by which the maximum speed is limited	—	Because a section length to allow a higher speed was not available on account of turnouts and sharp curve existing on the approach section	Same as ex. 1
C Name of line	—	Tokaido Line	Tokaido Line
D Section	—	Kanaya-Fujieda	Kanaya-Fujieda
E Length :			
1) Length the train ran at not less than 90 % of the maximum speed	km	5.2	4.0
2) Length of the section the running trial was made	km	10.1	12.0
F Date	—	From July 27, 1959 To July 31, 1959	Nov. 13, 1960 Nov. 22, 1960
G Number of runs at each maximum speed	times - km/h	1 - 163 1 - 161 1 - 153 1 - 141 1 - 131 1 - 125	1 - 175 1 - 174 1 - 172 13 - 160 6 - 140 3 - 130
H Number of personnel engaged in the test :			
On board	person	20	15
On ground	»	50	30
I Track structure (*)			
1) Gauge	mm	1 067	1 067
2) Rail weight	kg/m	50	50
3) Rail length	m	1 452, 1 233, 856, 400 and 25	1 452, 1 233, 848, 258, 200 and 25
4) Number of expansion joints	—	7	7
5) Spacing of sleeper	pcs/km	1 760	1 760
6) Kind of sleeper	—	Prestressed concrete sleeper, 1 kind	Prestressed concrete sleeper, 2 kinds Concrete sleeper, 1 kind

TABLE 131-1-(2).

	Unit	*Example 1*	*Example 2*
Rail fastening :			
Kind	—	Elastic fastening, 1 kind	Elastic fastening, 6 kinds
Spring constant of pad	ton/cm	100	100
Spring constant of clip	ton/cm	2.2	1.2 - 1.5
Tightening force	ton/clip	0.5	0.5
8) Kind of ballast	—	Crushed stone	Crushed stone
9) Diameter of ballast			
Principal ballast	mm	10 - 60	10-60, 20-50
Ballast of smaller size	mm	none	10-20, 20-30
10) Depth of ballast (below sleeper bottom)	mm	250	250
J Curve :			
1) Actual superelevation and max-mum passing speed :			
Radius of curvature 1 000 m	mm (km/h)	105 (150)	105 (150)
» 1 500 m	»	60 (143)	60 (140)
» 2 500 m	»	none	50 (175)
» 3 100 m	»	50 (163)	none
2) Average value of superelevation slope and form of diagram of super-elevation of transition curve (see ans. 221) :			
Radius of curvature 1 000 m	—	1/1 140 (Sine curve)	1/1 140 (Sine curve)
» 1 500 m	—	1/750 (Sine curve)	1/750 (Sine curve)
» 2 500 m	—	none	1/1 400 (Sine curve)
» 3 100 m	—	1/1 100 (Linear variation, with wave forms on both ends)	none
K Tolerance (mm) for track irregularities and percentage of aggregate length of tracks exceeding the tolerances (record taken by high speed track inspection car) :			
Gauge	mm, %		4 mm, 1 %
Alignment by 10 m string	mm, %		3 mm, 3 %
Distortion on 2.3 m	mm/m, %		0.8 mm/m, 1 %
Cross level	mm, %		4 mm, 3 %
Longitudinal level on 10 m chord	mm, %		5 mm, 2 %
Variation in gauge	mm/m, %		0.5 mm/m, 1 %
Variation in alignment	mm/m, %	—	0.8 mm/m, 2 %
Variation in longitudinal level	mm/m, %	—	0.8 mm/m, 3 %

TABLE 131-1-(3).

	Unit	*Example 1*	*Example 2*
L Rolling stock used in the running trial :			
1) Kind	—	Electric railcar	Electric railcar
2) Usage	—	Limited express train " Kodama "	Catenary testing car. (The electric railcars " Kodama " were also operated in the s me way as in example 1.)
3) Composition of train			
(Motored car)	—	4	1
(Trailer)	—	2	—
4) Axle weight			
(Motored car)	ton	9.5	11.5
(Trailer)	ton	8.0	—
5) Truck :			
Rigid wheel base	mm	2 100	2 500
Wheel diameter	mm	860	910
Kind of bolster spring	—	Air spring	Leaf spring
(deflection per unit load)	mm/t	Motored car 22.8 Trailer 23.6	6.2 —
Kind of axle spring	—	Coil spring 2 rows	Coil spring
(deflection per unit load)	mm/t	Motored car 15.1 Trailer 18.7	16.4 —
Lateral elasticity by	—	Swing bolster	Swing bolster
Year of manufacture	—	1958	1932
6) Height of gravity center	mm	(Motored car)	—
(above rail level)	—	1 100	1 110
M Result of measurement :			
1) Vibration acceleration of rail (average) :			
Section of long rails	g ($980 cm/sec^2$)	60	Not measured
Rail joint	g	200	Not measured
2) Maximum transversal thrust measured on board (calculated from strain in wheel spokes) :			
Straight	ton	1.7	1.8
Curve (R = 3 100 m or R = 2 500 m)	»	3.5	3.7
3) Maximum rate of Q/P (see ans. 122) :			
Straight		0.40	0.42
Curve		0.43	0.48
4) Vertical vibration acceleration of car body :			
Maximum at straight	g	0.12	0.13
Average at straight	»	0.05 - 0.08	0.05 - 0.09
Maximum at curve	»	0.13	0.16
Average at curve	»	0.04 - 0.09	0.09

TABLE 131-1-(4).

	Unit	Example 1	Example 2
5) Lateral vibration acceleration of car body :			
Maximum at straight	g	0.12	Not yet reviewed
Average at straight	»	0.05 or less	Not yet reviewed
Maximum at curve	»	0.09	0.14
Average at curve	»	0.07 or less	0.07 - 0.10
6) Vertical vibration acceleration of axle box	g	9	Not measured
7) Maximum deflection of axle spring :			
Straight	mm	8	Not measured
Curve	»	14	Not measured
8) Maximum deflection of bolster spring :			
Straight	mm	7	Not measured
Curve	»	11	Not measured
9) Maximum lateral deviation of swing bolster :			
Straight	mm	7	Not measured
Curve	»	13	Not measured

(*) Test runs were made on the same section in both Example 1 and Example 2. In the case of Example 2, a stretch of about 1.5 km was newly constructed for the test, where the track structure was different from the track of Example 1.

air-conditioned train in order to increase the speed of passenger trains, but the results of trials are yet being reviewed;

4) Irish Rys carried out a running trial at a speed of about 130 km/h for the purpose of locomotive testing, and the track was found satisfactory;

5) British Rys established a world speed record of 201 km/h with steam locomotive in 1938;

6) Japanese Rys recently carried out running trials at maximum speeds 163 km/h and 175 km/h on the narrow gauge track, for which the normal speed is 110 km/h. The purpose of these running trials was originally to obtain the data for high speed running, but it was also intended to utilize those data especially for the design of the New Tokaido Line on which trains are expected to run at the speed of 200 km/h. The summary of the running trials is shown in Table 131-1.

As the measuring method the wire strain-gauge and the vibration acceleration pick-up where mainly used both on the coach and the ground. The data thus obtained were electrically amplified and continuously recorded on the oscillograph paper. To ascertain the condition of the track, the high speed track inspection car which is able to record automatically the track irregularities at a speed of 100 km/h was used.

The main items and information obtained from the results of the high-speed running trials are as follows :

a) the vertical vibration acceleration of each part of the track structure such as rail, sleeper, ballast, etc. seems to increase with the train speed. Therefore, it is considered that the damage and deterioration of each part of the track structure, especially the

loosening and sinking of ballast, by the vibration acceleration, become more conspicuous as the train speed becomes higher (fig. 131-1, 131-2);

b) the pressure acting on each part of the track such as the pressure under rail-seat on a sleeper, the pressure acting on the road bed, etc. are not so much affected by the train speed. In other words, it is considered that if long welded rails are used for the track and the track is kept in a good condition beyond a certain extent, the pressure acting on each part of the track does not especially increase because of high-speed running (fig. 131-3, 131-4);

c) if the track before and after a bridge

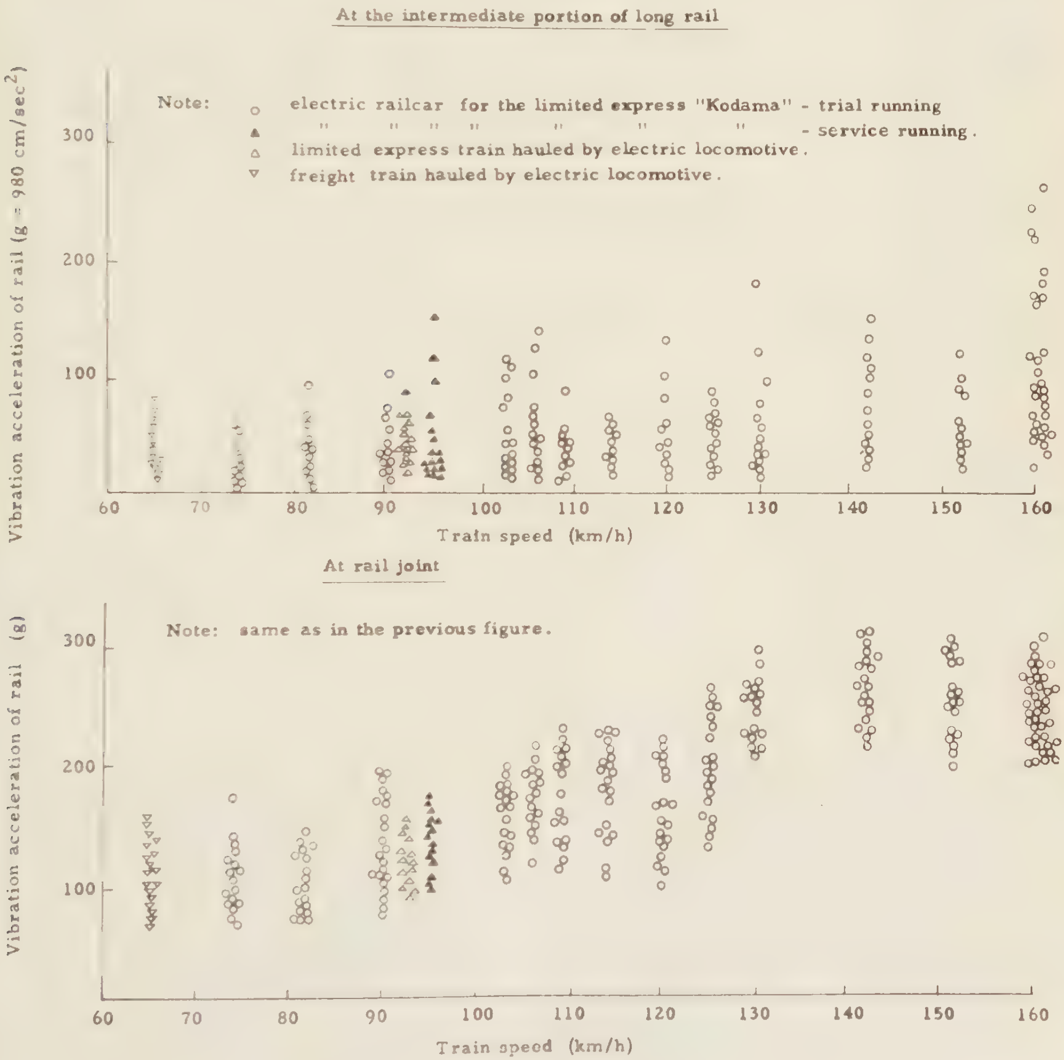


Fig. 131-1. — Vibration acceleration of rail.

is maintained in good condition, the stress in bridge girders does not increase so much with the train speed (fig. 131-5);

d) in order to examine the effect of the deflection of bridge girder on the high-speed running, the track at the pier was somewhat elevated, making a vertical angle lengthwise, and as a result of measuring the motion of high-speed train it has been revealed that the vertical vibration of coaches increased by 50-90 % at that point (see Answer 291);

e) it has been disclosed that the transversal thrust of train tends to increase with the running speed, and especially that the greater the irregularities of track are, the more conspicuous this tendency becomes (see Answer 132);

f) the acceleration of car body did not show such a big value as shown in 5) and 6, M in Table 131-1 (see Answer 133);

g) in case there occur large flats on the wheel tread and abnormalities in the inclination of the wheel tread, the acceleration of rail, the transversal vibration of bridge, the acceleration of car body, etc. become conspicuously large, and at a speed of 120 km/h they readily reach the limit, which has harmful effects beyond our expectation (see Answer 146):

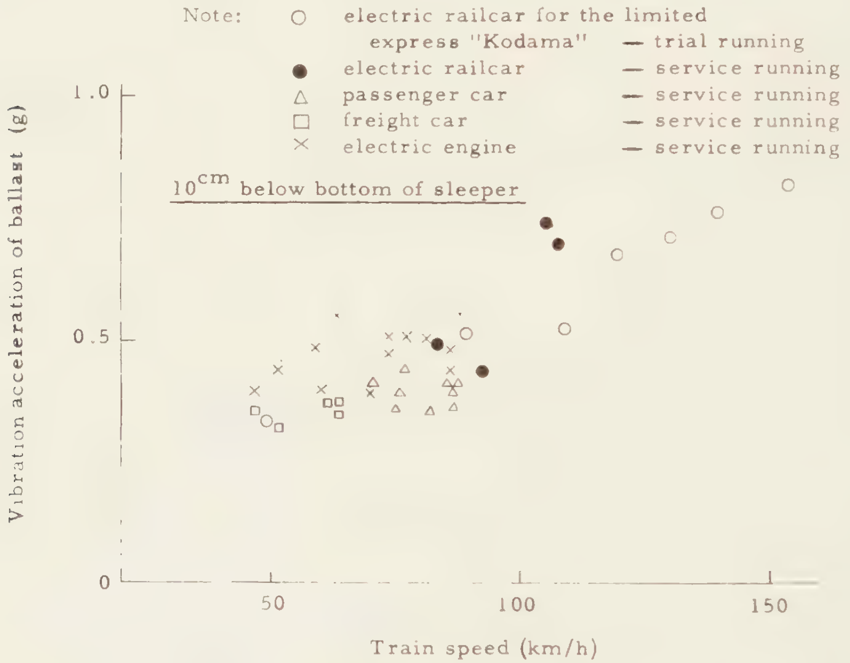


Fig. 131-2. — Vibration acceleration of ballast.

h) the transition curve for which the form of the diagram of super-elevation was assumed as a sine curve, showed a satisfactory riding quality (see Answer 221);

i) the maximum instantaneous wind velocity at a height of about 1 300 mm above rail level was measured with a train running at a speed of 150 km/h by means of a hot-wire anemometer, and the safety of workers on the path has been assured (fig. 131-6);

Moreover, as to the velocity of wind caused by the running train (train wind velocity)

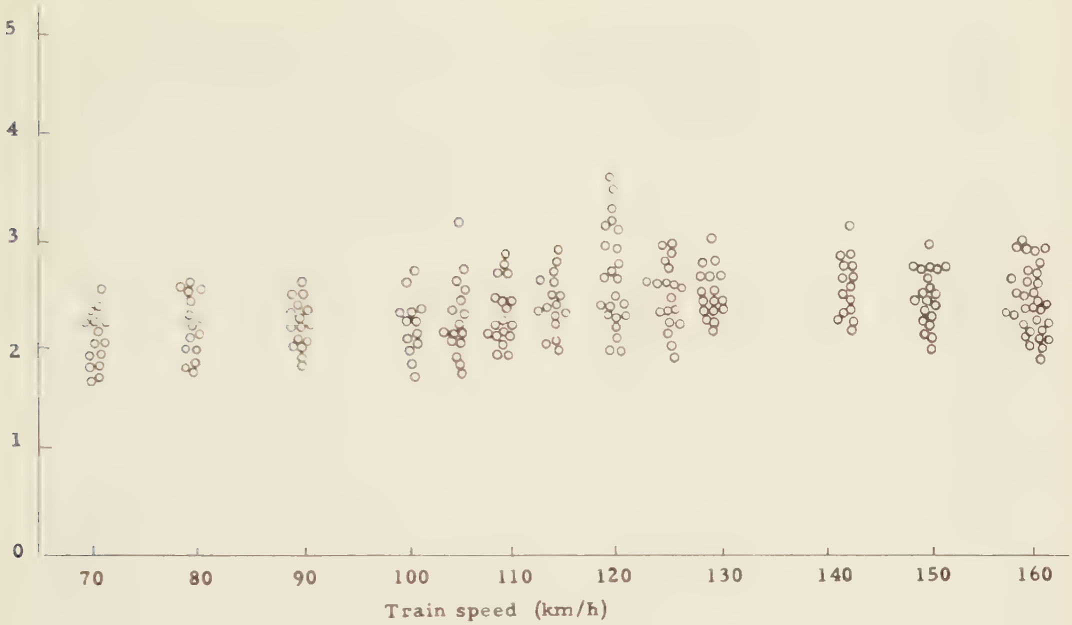


Fig. 131-3. — Pressure under rail-seat on a sleeper.

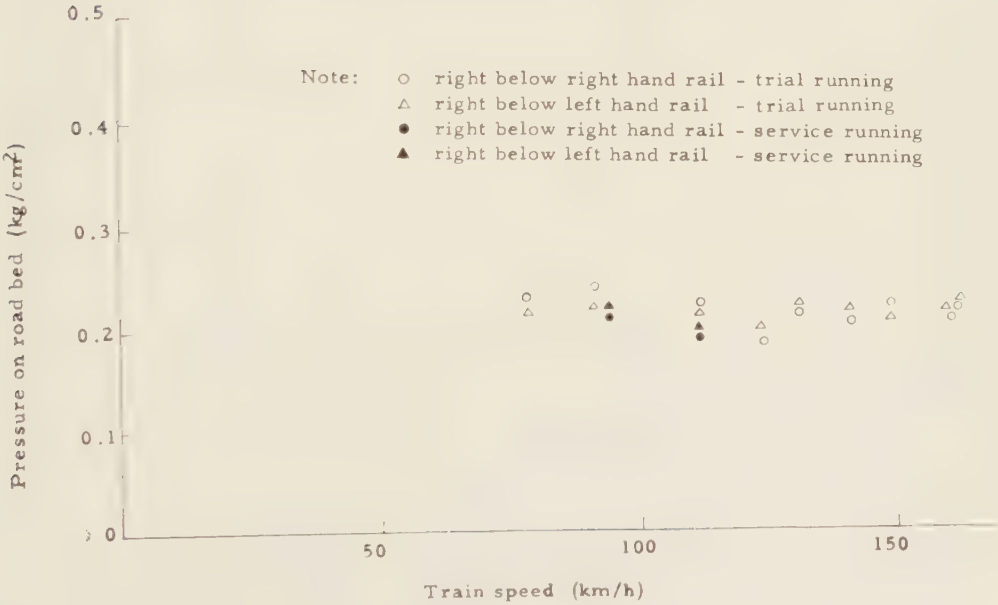


Fig. 131-4. — Pressure on roadbed.

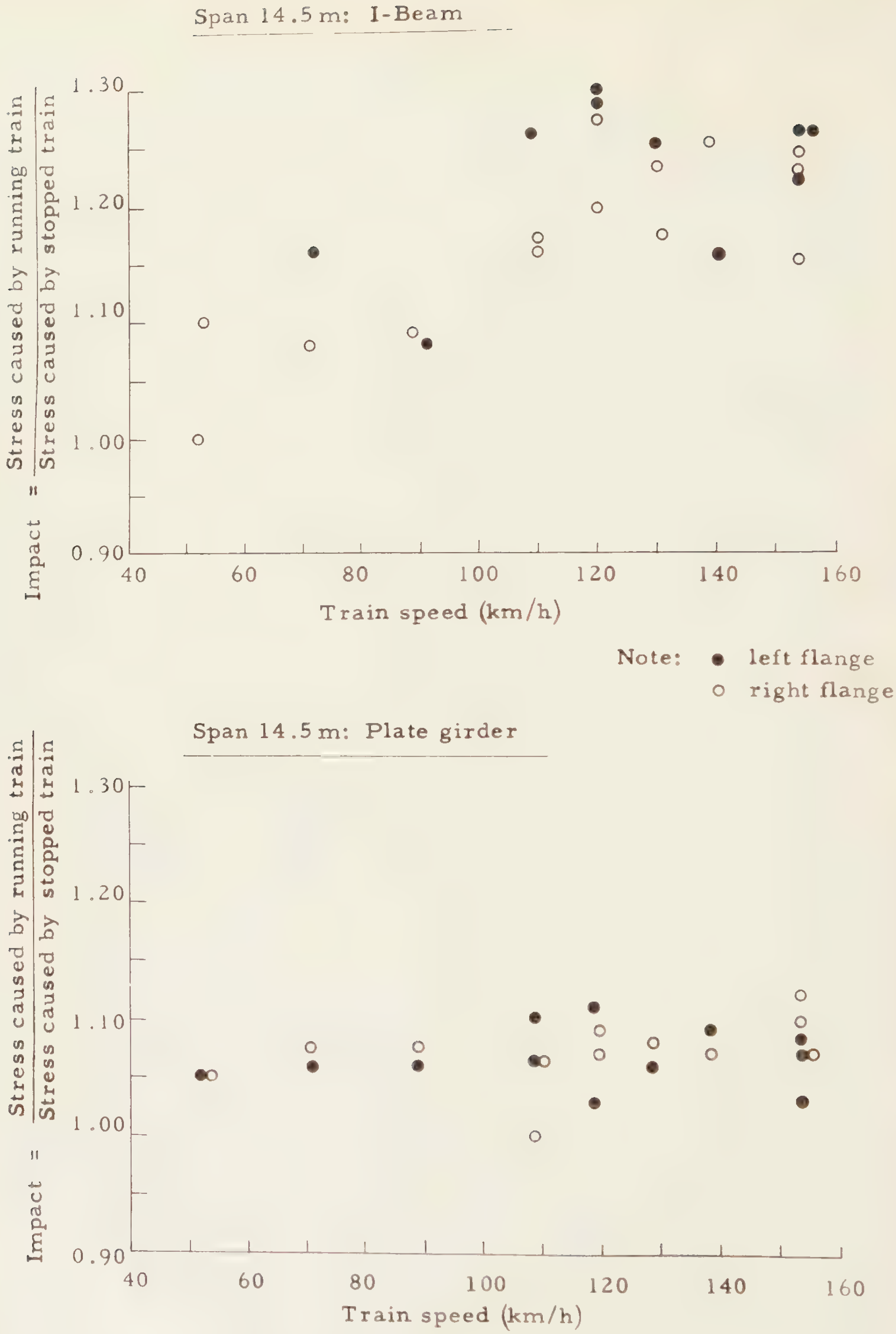


Fig. 131-5. — Stress in middle lower flange of girders.

on the surface of ballast, its ratio to the train speed, $\frac{\text{Train wind velocity}}{\text{Train speed}}$ has been found somewhere around 0.7, and it has been revealed that there is no possibility of ballast flying, even if the train runs at a speed of 200 km/h;

j) the irregularity of track affects the speed limit most, but it is not so much the

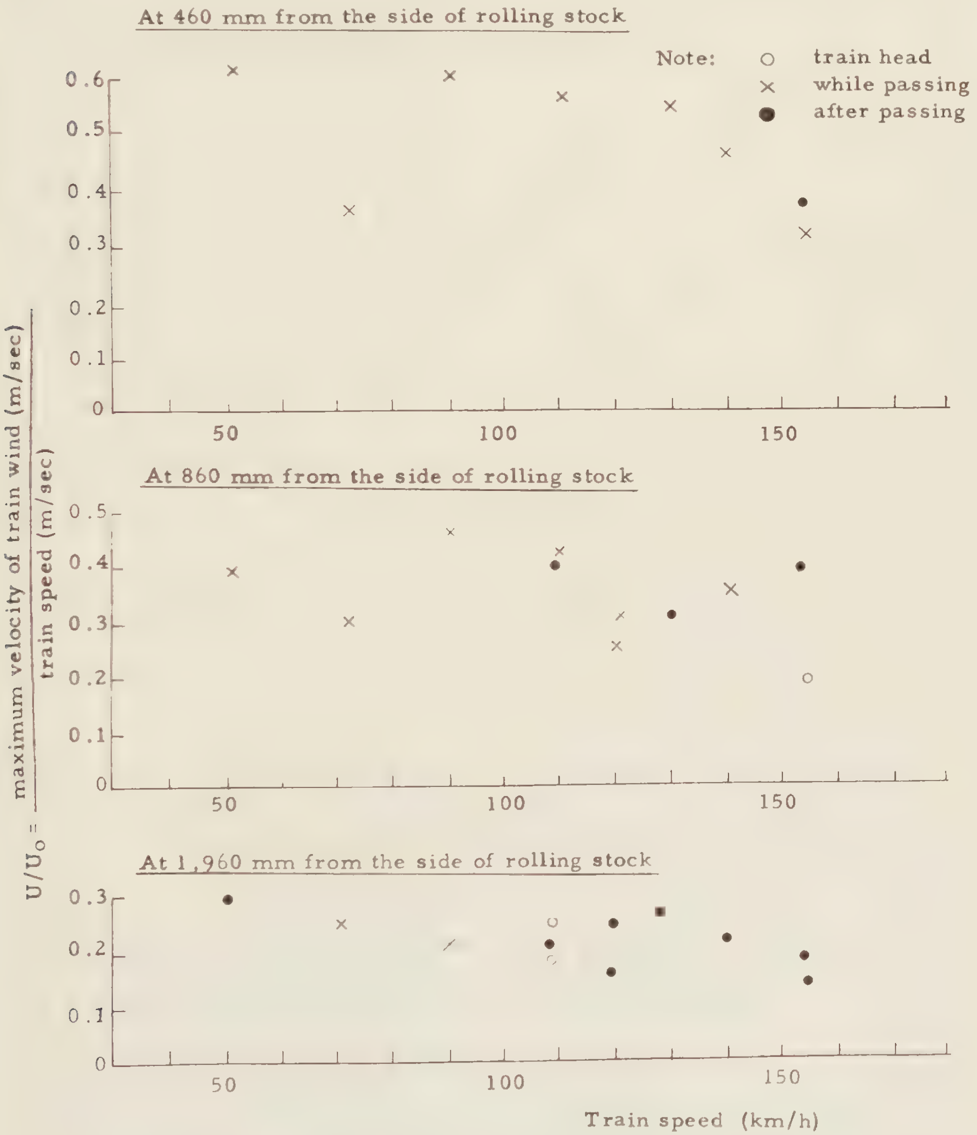


Fig. 131-6. — Train wind velocity at 1.3 m above rail level.

deviation from the specified values as its variation per metre of track that is important. For the running at a speed of 175 km/h the track condition as shown in Table 131-2 has been found quite satisfactory.

TABLE 131-2. — **Condition of the track.**

Date of measuring	Gauge			Cross level			Longitudinal level		
	m	σ	*p*	*m*	σ	*p*	*m*	σ	*p*
Nov. 17, 1960 . .	−1.3	1.3	10.3	0.3	1.6	5.8	0	1.7	7.0
July 30, 1959 . .	0.4	1.2	1.7	0.1	1.3	2.1	0.1	1.8	8.8

Date of measuring	Alignment			Distortion		
	m	σ	*p*	*m*	σ	*p*
Nov. 17, 1960 . .	0	1.4	3.0	0.3	1.1	1.3
July 30, 1959 . .	0	1.3	1.9	0.2	1.2	1.5

Note : (1) These data have been obtained from the record of the high speed track inspection car.

(2) *p* denotes the percentage of the aggregate length of tracks whose irregularities exceed 3 mm. As to the other symbols please refer to the Answer 535.13.

k) generally speaking, it has been revealed that so long as the track condition can be definitely kept to the extent as mentioned on item *j*, a speed of 175 km/h is safe even on the narrow gauge track and the tendency of track deterioration is not so serious.

Therefore, it is presumed that if the track construction is improved and strengthened to a certain extent, the running at a speed of 200 km/h, which is specified for the New Tokaido Line of standard gauge, is possible.

132. *Did these trials teach you anything about the increase in the transversal stresses as a consequence of the speed (on straight and on curves) and about the effects of emergency braking or sudden cutting off of the power supply to the engine (cutting off of traction current for example), when running at full speed?*

The transversal thrust varies to a certain extent according to the track condition. On straight as well as on curves it seems to increase with the train speed.

The data the Swedish Rys obtained from the actual measuring on a straight track are as shown in figure 132-1. The Swedish Rys reports that on a straight track the transversal thrust tends to increase with the speed and that its maximum forces occur with short duration at the same points of the line and also reports that on a curved track the average value of transversal thrust is considerably high and it tends to increase with the speed as is the case on a straight track.

Examples of the transversal thrust actually

measured by Japanese Rys are given in figure 132-2 and the tendency of the transversal thrust increasing with the speed on both straight and curved tracks was recognized. The magnitude of the transversal thrust was large on curves, and on straight section well kept in good condition the maximum transversal thrust was 1.7 tons or less even at a speed of 160 km/h.

The values Q/P, where P is the value of the dynamic wheel load and Q is the value of transversal thrust, measured simultaneously of the same wheel, did not tend to increase very much even when the speed increased, as seen from figure 132-3.

As to the emergency braking or sudden cutting off of the power, no serious effects have been recognized according to the answers of most railways. However, when Japanese Rys conducted running trials, it was found that the application of emergency brake caused certain flats on the wheel tyre, which were serious enough to hamper the following running trials, and Japanese Rys improved the brake system later.

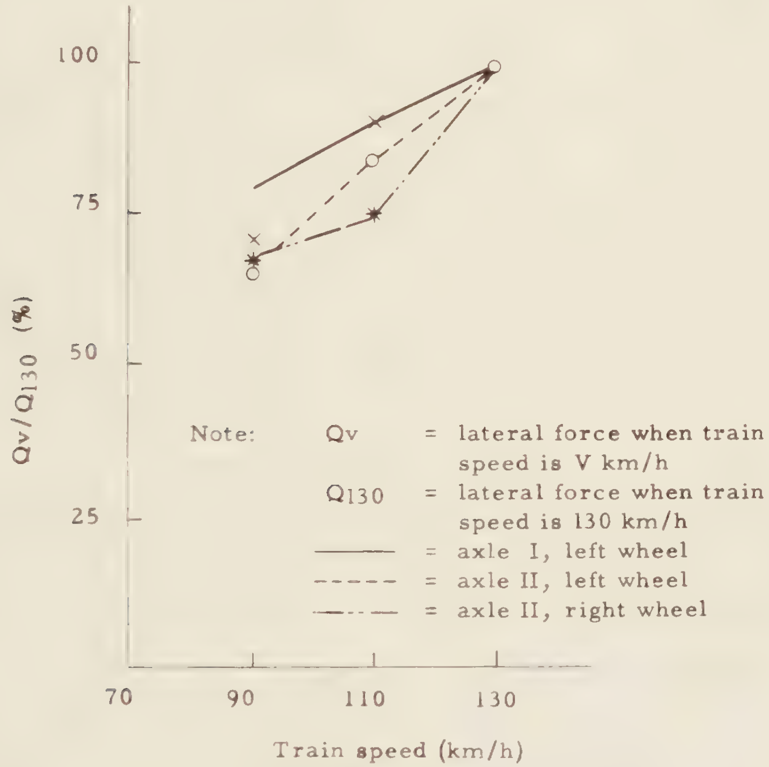


Fig. 132-1. — Transversal thrust and train speed.

133. *What trial results are available concerning the vertical acceleration of the rolling stock and its consequences upon stability of running?*

The measurement carried out by Swedish Rys at the time of running trials mentioned in Answer 131 disclosed that the frequency of the vertical oscillations of the rolling stock at three speeds — 90, 110 and 130 km/h

was extremely small and its average value was generally 2.3 cps.

When Japanese Rys carried out running trials mentioned in Answer 131, the riding quality of the rolling stock was found satisfactory even at a speed of 175 km/h (figure 133-1), and it was also found that the vertical vibration was comparatively larger on the expansion joint of long rail and on the bridge than on other parts of the track, tending to increase with the train speed.

On the other hand the coaches which compose the limited express train, « Kodama » and which are equipped with the air spring, thus making the bogie performance excellent, showed less tendency of the increase of vibration acceleration than in case of the catenary testing car. These findings are suggestive of the importance of the design of rolling stock (fig. 133-2).

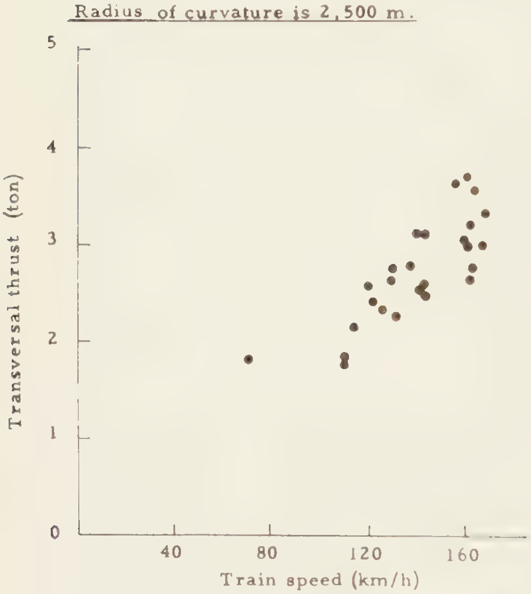


Fig. 132-2. — Transversal thrust and train speed.

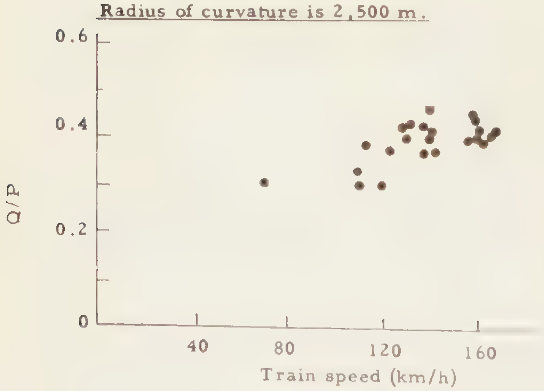


Fig. 132-3. — Q/P and train speed.

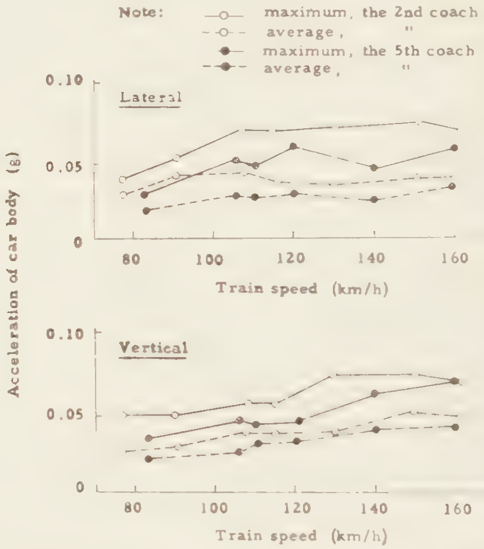


Fig. 133-1. — Vibration acceleration of car body on straight section.

The deflection of axle spring and bolster spring and the deviation of swing bolster of the electric railcar for the limited express, « Kodama » were measured. As a result, it has been revealed that they tend to increase as the train speed increases, but all are within the safety range (fig. 133-3).

14. *Considerations concerning rolling stock.*

Has your experience led you to formulate certain desirata concerning the characte-

ristics of the rolling stock to be used for high speed running, especially as regards:

141. *The axle-load.*

Inasmuch as the lighter axle load evidently causes less deterioration to the track, there are many countries where reduction of axle load or the unifying of axle load on each car by use of railcars is in progress.

alleviate the vibration, and that the greater the ratio of the suspended weight to the unsuspended weight is, the less the track deterioration will be. Here, the term, track deterioration means the loosening and sinking of ballast caused by passing of cars. The amount of this deterioration is considered to be proportional to the train speed, the sum of axle loads of the passing cars, the characteristics factor of car which is deter-

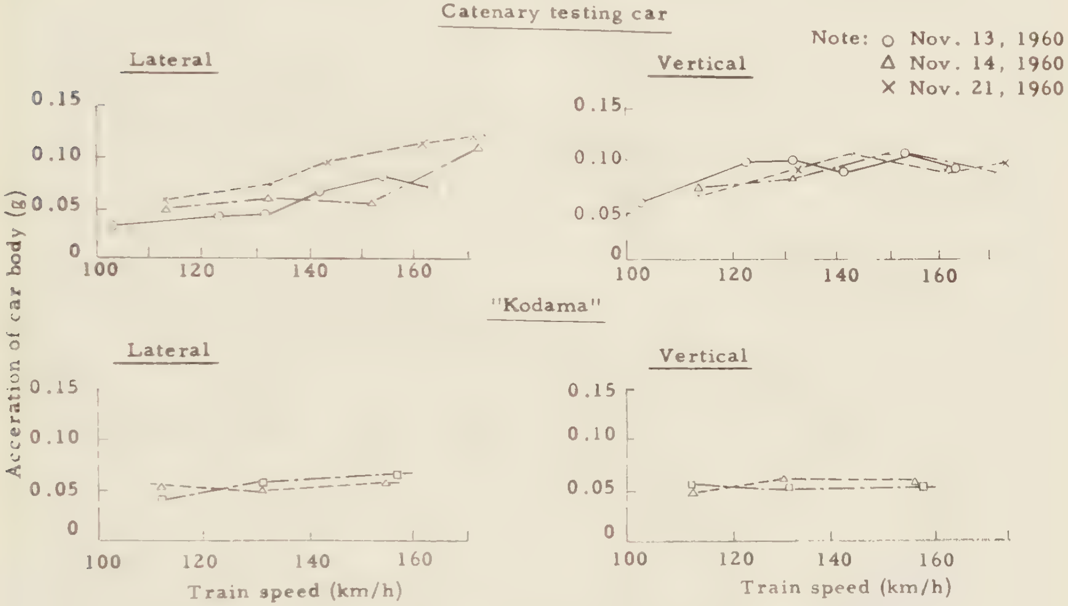


Fig. 133-2. — Vibration acceleration of car body at expansion joint.

142. *The suspended and non-suspended weight.*

There are many countries which answered that it would be better to make the unsuspended weight smaller. However, British Rys stated that although they preferred to keep the unsprung weight down, the possibly beneficial results due to fully sprung motors were marred by the characteristics of cerain types of quill drives in corporating springs.

Japanese Rys consider that it will be better to make the springs of car softer to mined by the performance of car spring and the ratio of the suspended weight to the unsuspended weight, etc.

143. *The height of the centre of gravity.*

As regards the vertical load (increase of wheel load) with respect to the track, it would be better that the height of the centre of gravity is lower, if the car vibration and the centrifugal force of a car at the time it passes on a curved track are taken into consideration. Especially on a curved track, lowering of the height of centre of gravity is effective for increasing a passing speed.

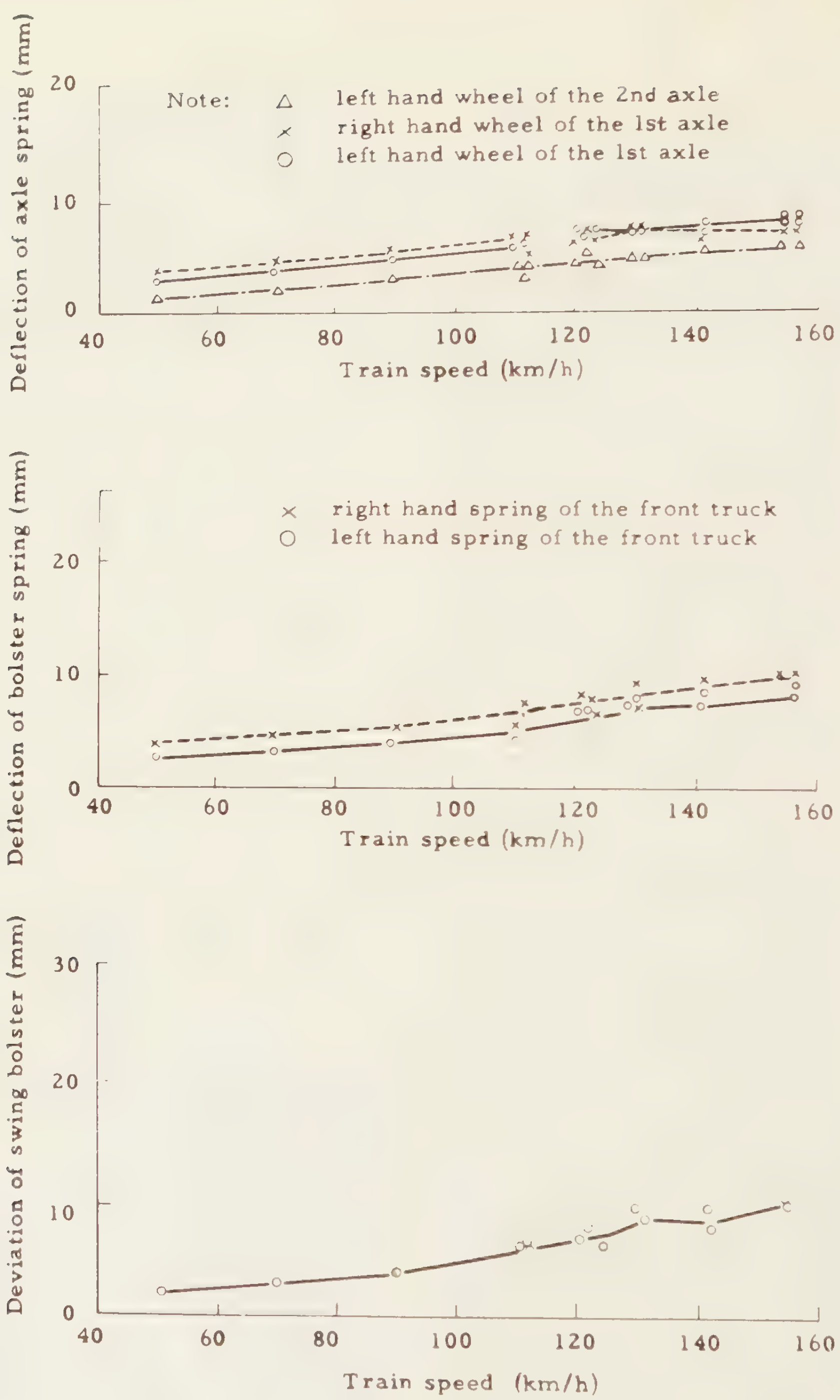


Fig. 133-3. — Deflection and deviation (5th coach of « Kodama »).

There is an opinion that a higher centre of gravity reduces the transversal thrust (Indian Rys and others).

144. *The diameter of the wheel and the ratio* $\frac{P}{d}$ *or* $\frac{P}{Vd}$ *where*

d diameter of wheel;

P wheel load;

V train speed.

There is a tendance that the larger the wheel diameter, d (m), is in comparison with the wheel load, P (ton), the smaller will be the contact surface stress at the contact point of the rail and tyre and the impact at turnout. However, there is also an opinion that the transversal thrust and the side wear of rails on a curved track will become larger.

British Rys use 5 as a statical value of P/d and Indian Rys, 5.5 In the *IRCA Bulletin* (May, 1954 issue) it was stated that P/d should be smaller than 8. Japanese Rys specifies the value of P/d as somewhere around 8 for the New Tokaido Line.

145. *The characteristics of the bogies (wheelbase, play, suspension, rotation).*

For the characteristics of the bogies to be used for high speed running it is desirable that the bogies are free from hunting, the springs are effective enough to isolate the vibration due to the track irregularities transmitted to the car body, and also that they do not cause a very large transversal thrust or dynamical axle load to the track.

The hunting of the bogie car may be classified into two kinds according to the experiment of Japanese Railways : the primary and the secondary.

The primary hunting occurs at a comparatively low speed and causes the car body to vibrate with a larger amplitude, while the secondary occurs at a higher speed with violent vibration of the bogie. The primary hunting can be prevented by making the natural frequency of the transversal car vibration due to the bogie spring system as low as possible and by applying a proper damping to the vibration.

To prevent the secondary hunting certain measures such as less inclination of the wheel tread, elimination of the axle side play, rigid support of the axle box, and application of frictional resistance against rotation of the bogie are considered effective.

For practical design on these points, however, choice of optimum values is necessary in consideration of ill effects : too flat wheel tread invites a one-sided contact between the wheel flange and the rail, and too large frictional resistance against the bogie rotation causes an abnormal side thrust against the rail.

Adoption of independent wheels may be a most effective hunting prevention, but it involves some difficulties in the practical use. For the New Tokaido Line of Japanese Rys, the test of full-scale experimental truck on a test platform has led us to estimate that there will be no need of independent wheels at a speed of somewhere around 200 km/h.

To reduce the vertical vibration of car body effectively Japanese Rys consider that it is desirable to keep the vertical natural frequency of the car body due to truck spring system at 1 cps or less. For this purpose use of the air spring is effective. Furthermore it is advantageous to arrange the spring in two stages with the ratio of flexibilities beween the axle spring and the bolster spring ranging between 1:2 and 1:3.

As to the alleviation of lateral vibration of car body, though most of the conventional cars utilize the swing bolster hangers, in case of the bogie equipped with air springs, simpler mechanism utilizing the lateral elasticity of the air spring itself is adopted.

146. *The conicity of the tyres and its effect upon rocking motion.*

There are many countries where the inclination of the tyre tread of 1/20 is common, while there are some countries where

an inclination of 1/40 is adopted for certain high-speed cars. It is generally recognized that the gentler the tyre tread inclination is, the longer the period of the rocking motion (hunting) is. But there are quite many opposite opinions against the cylindrical tyre.

There are many countries where it is considered that it would be better to lay the rail with an inward inclination which coincides with the inclination of the tyre tread. For the New Tokaido Line of Japanese Rys, the inclination of tyre tread is set at 1/40 and the rail is expected to be laid with an inward inclination same as that of the tyre tread.

To maintain the tyre tread in the correct form is important especially for high speed running, which may be proved by an example mentioned below. The high speed running trials carried out by Japanese Rys in 1959 with test cars, whose tyre treads happened to be of extraordinarily irregular inclination, revealed that the transversal vibration of girder became extremely large with the increase of train speed, because of the rocking motion (hunting) of the railcars, and it was judged dangerous for the high speed running (fig. 146).

147. *The effects of flats on the tyres.*

The flats on the tyres affect the track harmfully beyond expectation.

Swedish Rys report that when a flat reaches 40 mm or more in length, the car shall proceed to the nearest station at a very reduced speed.

Japanese Rys stipulate that in connection with the narrow gauge lines, when a flat 25 mm long occurs at two places or more and/or a flat 50 mm long occurs at one place the tyre shall be re-turned. Japanese Rys carried out an experiment on an electric railcar by artificially making flats of various lengths to find out the effect of the flats on the rolling stock and the track. The experiment revealed that the ratio of the bending stresses of rail with and without the flat and the ratio of the pressure under the railseat on a sleeper with and without the flat, increased nearly proportionally to the length of flat and these ratios tended to increase with the speed up to 40 km/h, beyond which they did not increase very much.

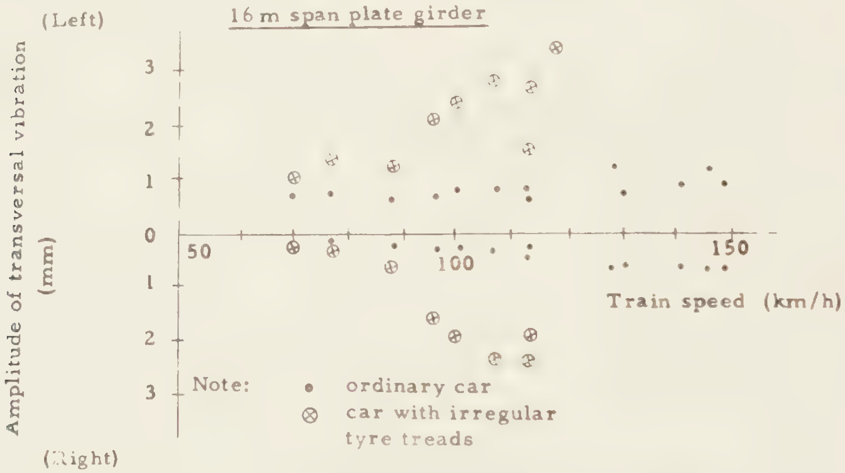


Fig. 146. — Transversal vibration of 16 m plate girder.

148. *The type of draw and buffing gear?*

British Rys use the buckeye drophead

type automatic coupler and the spring loaded gangways in all the post-war coaching stock; the screw couplings and hydraulic buffers in locomotives and railcars: and three-link chain coupling and hydraulic buffers in wagons. Indian Rys use the screw coupling drawgear and side buffers and state that these devices have no adverse effects to the track.

Japanese Rys use automatic couplers, and therefore no side buffers are used, but the damper acting in the transversal direction is installed above the vestibule diaphragm between cars to prevent the transversal motion of the cars, and so far it has been found satisfactory.

2. Layout of the line.

21. *Superelevation.*

The answers furnished by the various railways to the question on superelevation are outlined in Table 21.

211. *In calculating the theoretical superelevation ($K \frac{V^2}{R}$, K being a cœfficient depending on the gauge and the units used) do you take the maximum speed into account, or the maximum speed increased by a certain amount?*

Almost all the railways takes the maximum speed into account in calculating the theorical superelevation, as shown in Table 21.

212. *What do you consider as being the highest superelevation?*

As shown in Table 21, the highest superelevation is about 0.10 in most railways, as expressed in terms of ratio of superelevation to the distance between rail contact points of right and left wheels (C/G), and about 150 mm in the case of standard gauge. It is necessary to see that the highest superelevation is such that the cars passing over a curved track at low speed or coming to a halt there, are proof against overturn towards the inside through the wind from outside the curve and that the inclination of cars coming to a stop or passing slowly does not give any feeling of discomfort to the passengers.

In making calculation regarding an overturn towards the inside, the balance between the weight of car and the forces at work towards the inside, such as transversal force due to car vibration and wind force as a function of wind velocity is taken into consideration. From the condition of this balance, the wind velocity causing an overturn towards the inside can be obtained.

In the case of the New Tokaido Line of Japanese Rys, the calculation was made on the following assumption:

Car vibration is 0 at time of halt, and 0.1 g when the speed is 80 km/h or more; the wind force is indicated by the wind pressure on the side of car body, as obtained from the wind velocity; and the maximum superelevation is 200 mm, and the radius of curvature, 2 500 m. The wind velocity thus calculated is shown in figure 212. This shows that the lowest

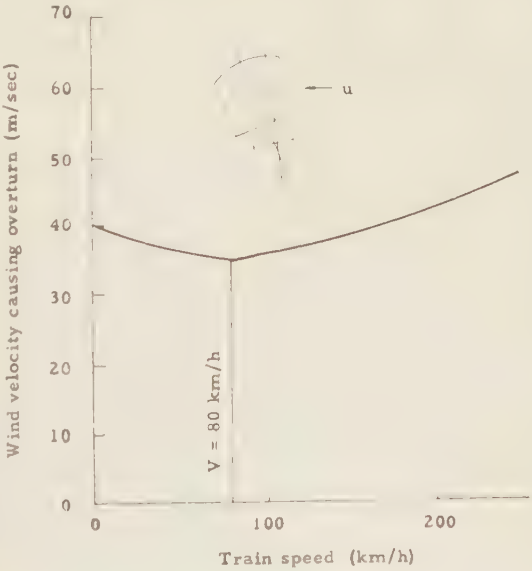


Fig. 212. — Wind velocity causing overturn towards the inside.

TABLE 21. — **Superelevation.**

Administrations and track gauges	*211. Speed in calculating the theoretical superelevation*	*212. Highest superelevation*	*213. Maximum deficiency in superelevation*	*214. Real superelevation*
British Rys . . . (1 435 mm)	Max. speed	153 mm	89 mm 51 mm	On a curve where all trains run at about the same speed, equilibrium superelevation is provided for this speed. On a curve carrying mixed trafic running at different speeds, a mean speed is selected.
C & O Rys . . (1 435 mm)	Max. speed	140 mm	76 mm	Substract a fixed constant of 76 mm
Egyptian Rys . . (1 435 mm)	Max. actual speed increased by a certain amount	150 mm	56 mm	5/8 of the theoretical superelevation.
Finnish Rys . . (1 524 mm)	Speed of the fastest train	150 mm	84 mm	$C = \frac{8V^2}{R}$ C : mm, V : km/h, R : m
Indian Rys . . . (1 676 mm)	Max. speed	140 mm 165 mm (in special cases)	76 mm	Superelevation calculated for 75 % of the max. permissible speed.
Irish Rys. . . . (1 601 mm)	Max. speed	152 mm 178 mm (exceptionally)	about 64 mm	Equilibrium superelevation only where 75 % or more of trains run at max. speed.
Japanese Rys *New Tokaido Line . . . . . (1 435 mm)* *Narrow gauge Lines . . . . (1 067 mm)*	 Max. speed Max. speed	 180 mm 105 mm	 60 mm 50 mm	 Superelevation calculated for about 90 % of the max. speed. Superelevation calculated as a function of the speed and the kind of trains ranging from : 105 to $\frac{8.4V^2}{R}$ — 50 (mm)
Rock Island Rys . (1 435 mm)	Max. speed	152 mm	76 mm	Theoretical superelevation minus 76 mm.
Seaboard Rys. . (1 435 mm)	Max. speed	165 mm	51 mm	—
Soviet Rys . . . (1 435 mm)	Square means of the speeds of annual passing trains	150 mm	100 mm	—
Swedish Rys . . (1 524 mm)	Max. speed	150 mm	100 mm	$C = \frac{8V^2}{R}$
T & P Rys. . . (1 435 mm)	Max. speed	140 mm	76 mm	—

value of wind velocity causing an overturn would occur while the train is passing at a comparatively low speed of 80 km/h, rather than while the train is at a halt, and it would be in the neighbourhood of 35 m/sec. This value roughly corresponds to the wind velocity of 38 m/sec which would come very near overturning a car towards the outside (see Answer 213). Since, however, some other force from outside, which was not included in the calculation, might be taken into consideration, the highest superelevation was safely estimated at 180 mm ($C/G = 0.12$), instead of at 200 mm.

213. *How much deficiency in superelevation do you allow (= theoretical supertelevation - real superelevation) for trains, electric railcars and rail motor coaches?*

As shown in Table 21, the value of the maximum deficiency in superelevation, if expressed in terms of the ratio (C_d/G) of maximum deficiency in superelevation to the distance between rail contact points of right and left wheels, is from 0.04 to 0.07, or, in the case of the standard gauge, 60 to 100 mm.

The allowable maximum deficiency in superelevation may well be determined by taking into consideration the least allowable riding quality due to the uncompensated centrifugal force at work at the moment the train passes the point and the security of the train from a possible derailment or overturn towards the outside when the car vibration and wind force are added thereto. In making calculation regarding an overturn towards the outside, consideration is given the same way as in the case of overturn towards inside.

For the New Tokaido Line, the wind velocity which would cause an overturn towards outside was calculated to be 38 m/sec at the deficiency in superelevation of 100 mm on the same assumption as in Answer 212. But, because trains are expected to be operated at a super-high speed there, the actual maximum deficiency in superelevation is fixed, to be on the safe side, at 60 mm ($C_d/G = 0.04$), taking into consideration unfortunate cases such as derailment, which might possibly happen before an overturn takes place.

214. *On a section of line, do you take the real superelevation as being equal to a fixed fraction of the theoretical superelevation? If so, how do you fix this fraction as a function of the speed and the kind of trains?*

In principle, the real superelevation is determined in such a way that, in the case of trains run at the highest speed, it is within the limit of the maximum allowable deficiency in superelevation, and that, in the case of trains run at lower speeds, superelevation is not given to the extent of impairing track maintenance and riding quality. Generally speaking, however, different real superelevations are fixed for different lines where trains of different kinds and speeds are operated. As shown in Table 21, in most cases the real superelevation is in the neighbourhood of 70% of the theoretical superelevation. For the New Tokaido Line, the plan is as outlined below:

Two kinds of rolling stock — 200 km/h multiple-unit electric passenger railcars and 130 km/h electric freight cars — are to be used. But the number of passenger railcar trains is expected to be predominant. The superelevation is obtained in such a way that the ballast settlement under the inner rail on a curved track is the same as the ballast settlement under the outer rail. The value of such superelevation corresponds to about 90 % of the speed of passenger electric trains (highest speed). (This calculation is based on the consideration of ballast settlement as in Answer 142.)

22. *Transition curves.*

The answers to the questions on transition curves are outlined in Table 22.

TABLE 22. — **Transition curves (1)**

	221. *Form of transition curve*	222. *Length of transition curve*	223. *Running out the superelevation*	
			Rule of proportionality of superelevation to curvature	*Superelevating a track*
British Rys .	Cubic parabola	$l = 0.0074$ CV C : mm l : m V : km/h	Applied	The outside rail is raised.
C & O Rys .	AREA ten chord spiral	$l = \frac{30.5 \text{ D}}{a}$ D : degree of circular curve a : increase in degree of curvature per 30.5 m station along the spiral	Applied	The outside rail is raised.
Finnish Rys. .	Cubic parabola	$l = 0.8$ C	Applied	In a normal case, the outside rail is raised.
Indian Rys . .	Cubic parabola	One of the following values whichever is the greater $l_1 = 0.0074$ CV $l_3 = 0.72$ C $l_2 = 0.0074$ C_dV C_d : mm	Applied	The outside rail is raised.
Irish Rys . .	Cubic parabola	$l = 0.0066$ CV	Applied	The outside rail is raised.
Japanese Rys *New Tokaido line*	Transition curve with sine curve for running out superelevation	One of the following values whichever is the greater $l_1 = 0.0062$ CV $l_2 = 0.0075$ C_dV	Applied	The superelevation is divided over the two stretches of rails by raising one and lowering the other.
Narrow gauge lines	Cubic parabola	One of the following values whichever is the greater $l_1 = 0.010$ CV $l_3 =$ C $l_2 = 0.009$ C_dV	Applied	The outside rail is raised.
Rock Island Rys	AREA ten chord spiral	$l = 0.0088$ CV	Applied	The outside rail is raised.
Seaboard Rys.	Spiral	$l = 0.94$ C	Applied	The outside rail is raised.
Swedish Rys .	Cubic parabola	For speeds of 120-130 km/h. (building new railway / maintaining existing tracks) desirable length 300 000/R 0.010 CV normal length 240 000/R 0.008 CV minimum length 180 000/R 0.006 CV	Applied	As a rule, the outside rail is raised.
Soviet Rys . .		$l = 1.2$ C		The outside rail is raised.
T & P Rys .	AREA ten chord spiral		Applied	The outside rail is raised.

TABLE 22. — **Transition curves (2).**

	224. *Diagram of versines in comparison with that of the superelevation*	225. *Concordance between the transition curve and the running-out zone of the superelevation*	226. *Maximum value of the super-elevation slope*	227. *Maximum value of the superelevation slope on the location of turnouts*	228. *Maximum variation per second of the superelevation and the deficiency superelevation*
British Rys .	The superelevation is made equal to the versine on a chord whose length (in m) is 0.31 V (in km/h)	Normally yes	3.33/1 000	Not laid down	Max. variation of the super-elevation 57 mm/sec
C & O Rys .	—	Run out the full length of spiral	—	Turnouts are kept out of curves	Max. variation of the super-elevation 32 mm/sec
Egyptian Rys	—	Yes	2/1 000	2/1 000	—
Indian Rys .	The superelevation is made equal to the versine on a chord whose length (in m) is 0.32 V (in km/h)	Yes	2.8/1 000	No change of superelevation between points 18.30 m outside of toe of switch and nose of crossing	Max. variation of the super-elevation 38 mm/sec Max. variation of the deficiency in superelevation 38 mm/sec
Irish Rys . .	Linear variation	Yes	1.34/1 000	—	Max. variation of the super-elevation 42 mm/sec
Japanese Rys New Tokaido Line	Sine curve	Yes	1/1 000	—	Max. variation of the super-elevation 45 mm/sec Max. variation of the deficiency in superelevation 37 mm/sec
Narrow gauge lines	Linear variation, rounded in a short section at both ends of the superelevation slope	Yes	1/1 000	—	Max. variation of the super-elevation 28 mm/sec Max. variation of the deficiency in superelevation 31 mm/sec
Rock Island Rys	—	Run out the full length of spiral	—	—	Max. variation of the super-elevation 32 mm/sec
Seaboard Rys	—	Yes	1.07/1 000	Turnouts are not placed on curves	Max. variation of the super-elevation approximately 32 mm/sec
Swedish Rys .	Linear variation, rounded on a length of 10 m at both ends of the superelevation slope	Yes	2.5/1 000	No special rule	Max. variation of the super-elevation 46 mm/sec Normal variation 35 mm/sec Desirable variation 29 mm/sec
Soviet Rys .	—	Yes	3/1 000	—	—
T & P Rys .	—	Yes	—	Turnouts are usually avoided	Max. variation of the super-elevation 32 mm/sec

221. *What form of transition curve do you make use of?*

The cubic parabola is used in most cases. One of the drawbacks of the transition curve represented by a cubic parabola is that a both ends of the transition curve (BTC and BCC or ETC and ECC) the variation of superelevation becomes discontinuous, as shown in figure 221-1.

Actual survey has revealed that train vibration occurs, in most cases, at BTC (ETC) and BCC (ECC). This trend seems to grow with the increase of train speed.

To make up for the drawback referred to above in some of the railways, e.g. Swedish Rys and narrow-gauge lines of Japanese Rys, etc., wave forms of a transition curve are made use of near the BTC (ETC) and BCC (ECC).

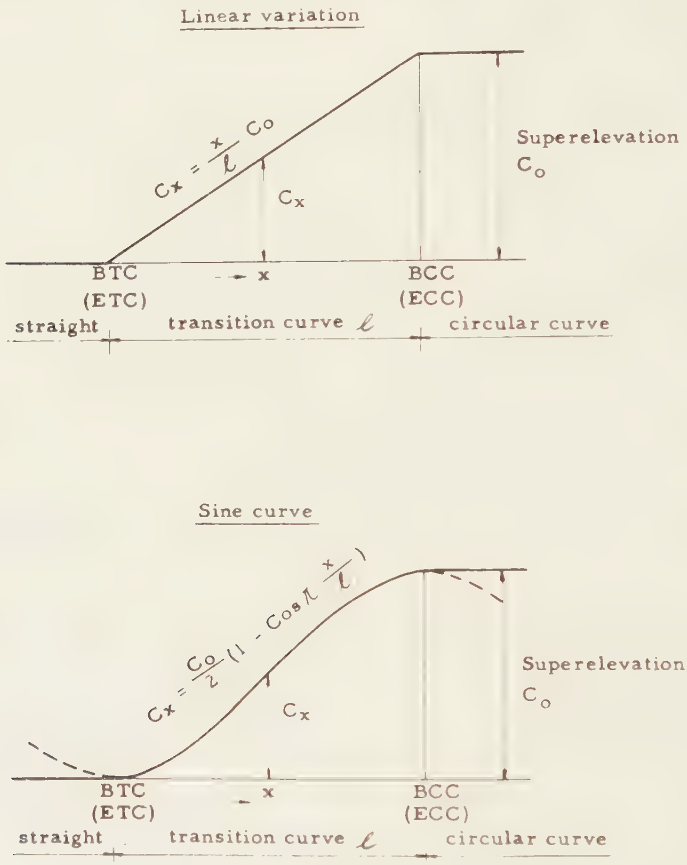


Fig. 221-1. — Diagram of superelevation.

Where the New Tokaido Line is concerned, the diagram of superelevation, as shown in figure 221-1, is to be a sine curve and the form of transition curve is to correspond to such diagram.

This form of transition curve may be worked out mathematically, as follows:

To obtain the superelevation C_x, we have

$$C_x = \frac{C_o}{2}\left(1 - \cos\pi\frac{x}{l}\right),$$

where l is the length of transition curve, C_o is superelevation of the circular curve. The curvature being proportional to the superelevation, we have

$$\frac{1}{r} = \frac{1}{2R}\left(1 - \cos\pi\frac{x}{l}\right),$$

where $\frac{1}{r}$ is curvature at point x from BTC.

With

$$\frac{1}{r} = \frac{d^2y}{dx^2}$$

given, the form of the transition curve with sine curve for running out superelevation is expressed in the following formula :

$$y = \frac{1}{2R}\left\{\frac{x^2}{2} + \frac{l^2}{\pi^2}\left(\cos\pi\frac{x}{l} - 1\right)\right\}$$

Figure 221-2 shows a comparison between transition curves with linear variation and

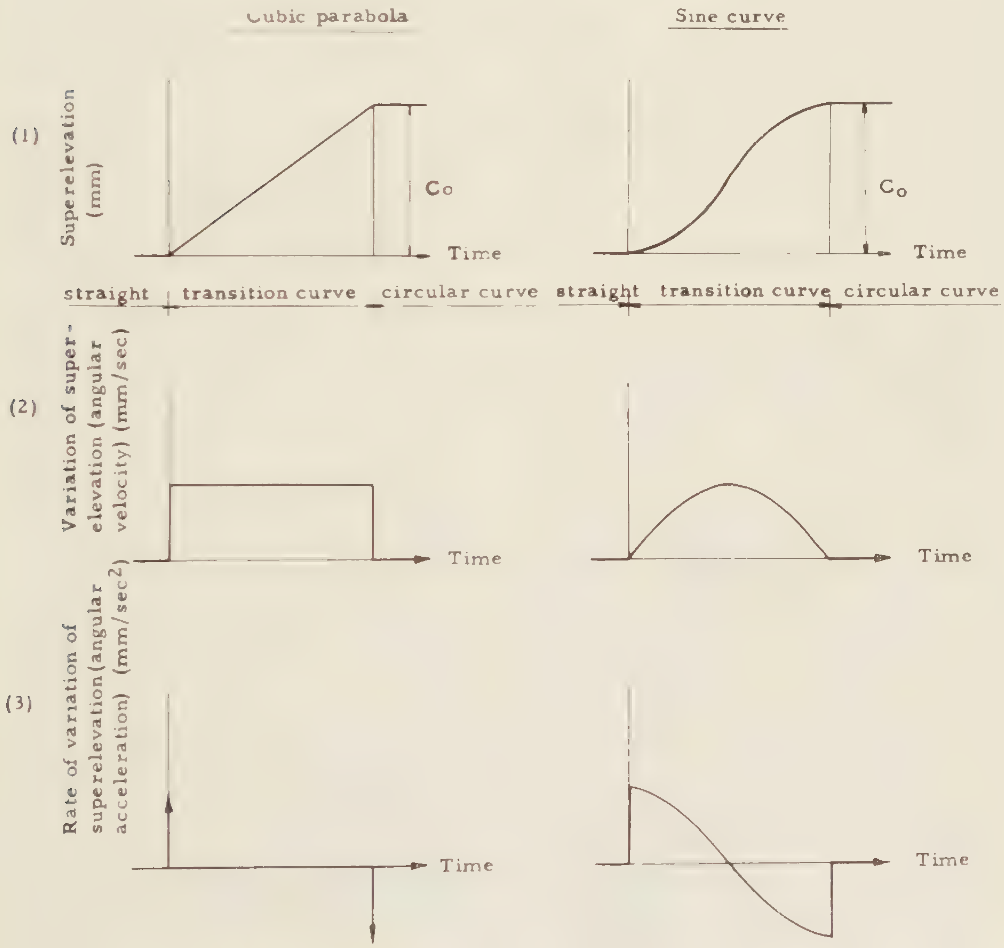


Fig. 221-2. — Comparison between two transition curves.

sine curve for running out superelevation. It will be noted that, in the case of linear variation for running out the superelevation, the angular acceleration at the points of BTC and BCC becomes infinite, while in the case of sine curve for running out the superelevation, is has a finite value, which may improve riding quality. Furthermore, a transition curve with sine curve for running out superelevation seems to improve the riding quality even when there is a short straight section between two curves.

The transition curve referred to above was used in the high speed test section and the result was satisfactory.

222. *How do you determine their length?*

The length of a transition curve is determined by one of the following three formulae or a combination thereof, adopting the highest value of all:

$$l_1 = k_1 \, C,$$
$$l_2 = k_2 \, CV, \quad \text{and}$$
$$l_3 = k_3 \, C_d V.$$

In these formulae k is a constant determined by respective conditions, C is actual superelevation (mm), C_d is deficiency in superelevation (mm) and, V is speed (km/h).

1) $l_1 = k_1 \, C$

In this old and common formula the length of transition curve is determined by the multiples of superelevation. But in high speed operation, where the riding quality especially counts, it seems difficult to obtain reasonable results in accordance with this old formula, if and when transition curves are determined regardless of train speed.

2) $l_2 = k_2 \, CV$

This formula is resorted to in obtaining the length from the limit of the variation per second of superelevation. We have:

$$l_2 = \frac{V}{3.6} \cdot \frac{C}{ct}, \therefore k_2 = \frac{1}{3.6 \, ct}$$

where ct is limit of the variation per second of superelevation (mm/sec).

The examples given by the various countries are given in Table 22.

3) $l_3 = k_3 \, C_d V$

This formula is used in obtaining the length from the limit of the variation per second of uncompensated centrifugal force, and is expressed as follows:

$$l_3 \quad \frac{V}{3.6} \cdot \frac{C_d}{C_{d,t}}, \therefore k_3 = \frac{1}{3.6 \, C_{d,t}}$$

where $C_{d,t}$ is limit of the variation per second of deficiency in superelevation (mm/sec).

The examples given by the various countries are given in Table 22.

223. *How do you run out the superelevation, in particular: do you apply the rule of proportionality of superelevation to curvature, do you divide the superelevation over the two stretches of rails by raising one and lowering the other?*

As show in Table 22, most countries adopt a formula in which superelevation is proportional to curvature.

In most countries superelevation is given by raising the outside rail, leaving the inside rail as it is. By so doing the centre of gravity of car moves up or down on transition curves. To avoid such shifting of the centre of gravity, many countries resort to a method whereby the inside rail is lowered by 1/2 C and the outside rail is raised by 1/2 C. This method is also to be applied to the New Tokaido Line.

224. *What have you to say about the diagram of versines in comparison with that of the superelevation (linear variation, wave form, etc.)?*

In each country the versine is proportional to the superelevation. In most cases, the form of the diagram is linear; that is, the layout takes the form of a cubic parabola.

In Swedish and Japanese (narrow gauge lines) Rys the versine diagram, when the cubic parabola is used, takes wave forms near the BTC (ETC) and BCC (ECC) points of a transition curve. In the case of the New Tokaido Line, however, the form of the versine diagram is a sine curve, but even in this case the versine is proportional to the superelevation all the same.

225. *Is there always a certain concordance between the transition curve and the running-out zone of the superelevation?*

As shown in Table 22, the running-out zone of the superelevation is kept in concordance with the length of transition curve in all countries.

226. *What is the usual maximum value (in $^0/_{00}$) of the superelevation slope?*

As shown in Table 22, the examples given in all the answers indicate that the maximum value of superelevation slope ranges from 1 $^0/_{00}$ to 3 $^0/_{00}$.

227. *What is the maximum value of this slope on the location of turnouts?*

There are few cases where superelevation is resorted to at turnouts. The maximum value is very much the same as in Answer 226.

228. *What is the maximum variation per second of the superelevation and the deficiency in superelevation for trains, railcars and rail motor coaches?*

The maximum variation per second of superelevation is specified, as shown in Table 22, in almost every country and is used as a basis for calculation of the length of a transition curve. It ranges from 28 mm/sec to 57 mm/sec.

The maximum variation per second of deficiency in superelevation is specified in Indian, Japanese and some other railways, and is likewise used as a basis for calculating the length of a transition curve. It ranges from 31 mm/sec to 38 mm/sec as shown in Table 22.

229. *How do you increase the length of existing transition curves when this is found to be necessary?*

To increase the length of the existing transition curves, recalculation is made in Swedish Rys in regard to the layout of the whole curve, or else calculation by the Halenz-Höfer string-lining method is adopted. In Indian Rys the string-lining method is used. In recent years there have been quite a number of cases in which the existing transition curves have been prolonged. With Japanese Rys, measures are taken as shown in figure 229. In increasing the length of a cubic parabola transition curve in such a way that the form of the cubic parabola will be retained, the curve has to be shifted over a fairly long section including circular curve, as shown in figure 229 (1) or (2). But if and when cubic parabola transition curve is converted to transition curve with sine curve for running out superelevation, the length of transition curve can be conveniently increased by shifting slightly the track on the transition curve, as shown in figure 229 (3). Therefore, transition curves with sine curves for running out superelevation are mostly used for increasing the length of transition curves. Calculation is made either mathematically or by the use of a curve adjustment calculator. In case a short straight section lies between reverse curves, a method is adopted in most countries of prolonging transition curves in such a way that they are tangential to each other, thereby eleminating the short straight section between them.

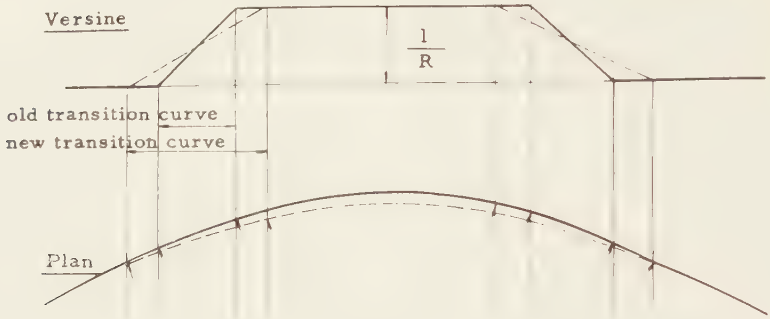
23. *Maximum permitted speed.*

Table 23 gives an outline of the answers on these questions.

231. *How do you determine the maximum speed to be permitted on a curve as a function of the curvature and the superelevation? Cases of curves with and without transition curves.*

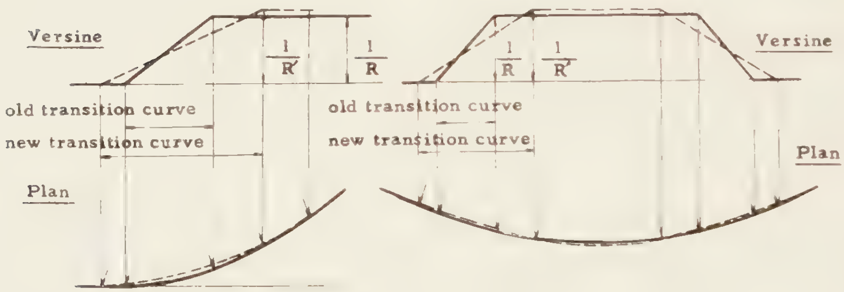
Figure 231 shows graphically the maximum permitted speed in each railway concerned. The maximum permitted speed on a curve may possibly be calculated by

1) When radius of curvature of circular curves is not changed.



2) When radius of curvature of circular curve is changed.

a. Change is made in part. b. Change is made in whole.



3) When cubic parabola transition curve is converted to transition curves with sine curve for running out superelevation. (Radius of curvature of circular curve is not changed.)

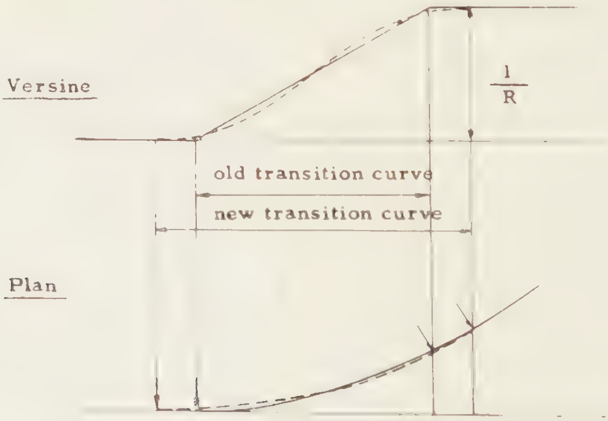


Fig. 229. — Method of increasing transition curve length.

TABLE 23. — **Maximum permitted speed.**

	231. *Max. speed to be permitted on a curve*	232. *Special rule in the case of curves (in the same sense or in opposite sense) separated by a short straight section (double junctions and crossovers)*
British Rys . . .	$V = \sqrt{(7.5 + 0.064\ C)\ R}$ V : km/h C : mm R : m	$V = 2.03\ \sqrt[3]{(l + 12.4)\ R}$ l : length of straight between crossings in m
C & O Rys . . .	$V = 4.2\sqrt{R}$	Applied
Finnish Rys . . .	$V = 0.395\sqrt{CR}$	
Indian Rys . . .	$V = 4.3\sqrt{R - 68}$	Speed restricted to 16 km/h
Japanese Rys *New Tokaido Line*	$V = 4.5\sqrt{R}$ R [illegible] 2 000 m	When $l \leqslant 19$ m $V = 2.05\sqrt[3]{R(19 + l)}$ $l > 19$ m $V = 6.9\sqrt[3]{R}$
Narrow gauge lines	$V = 3.0\sqrt{R} \sim 3.8\sqrt{R}$	The same as speed to be permitted on the turnouts at both sides
Seaboard Rys . .	$V = 4.3\sqrt{R}$	
Swedish Rys . .	$V = \sqrt{\frac{CR}{8}}$ $V = \frac{1\ 000\ l}{8\ C}$ l : length of transition curve in m	When l [illegible] $\frac{V}{10}$ $V = 2.9\sqrt{R}$ l [illegible] $\frac{V}{10}$ V [illegible] $10\ l$
Soviet Rys . . .	$V = \sqrt{(0.08\ C + 13\ p)\ R}$ p : uncompensated centrifugal acceleration, permitted to 0.7 m/sec²	

determining the actual superelevation and the deficiency in superelevation. But in this case the value of actual superelevation and the value of deficiency in superelevation do not necessarily represent a combination of their respective maximum permitted (British Rys, Swedish Rys and narrow-gauge lines of Japanese Rys).

For the New Tokaido Line, calculation was made by taking the highest superele-

vation to be 180 mm and the amount of maximum deficiency in superelevation to be 60 mm. We have $V = 4.5 \sqrt{R}$.

If the radius of curvature is 2 000 m or more, a train can pass over the curve at a

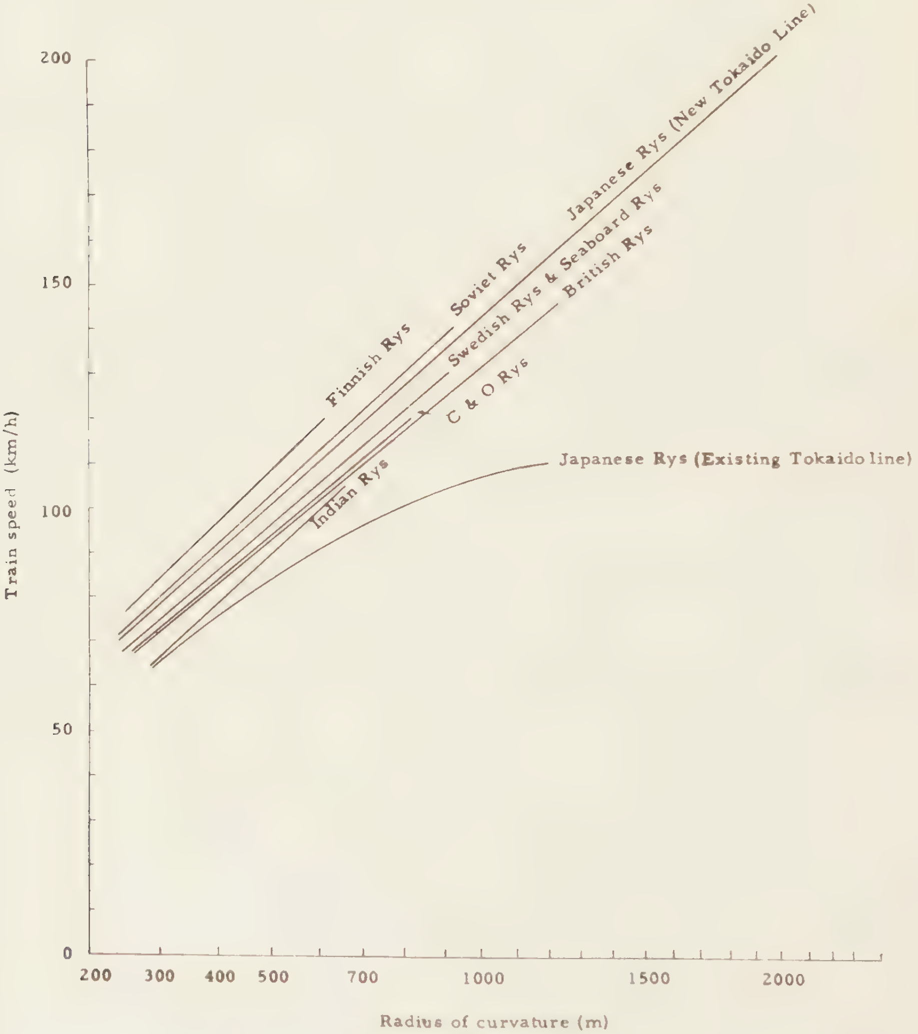


Fig. 231. — Maximum permitted speed on a curve.

speed of 200 km/h. In reality, no curve of which the radius of curvature is less than 2 000 m is used, except in special cases.

232. *Do you apply any special rule in the case of curves (in the same sense or in opposite sense) separated by a short straight section, as is the case with double junctions and crossovers?*

The answers are given in Table 23. Provisions seem to have been made for British Railways and for the New Tokaido

TABLE 24. — **Special layouts.**

	241. Minimum length for a straight section on the plain line between two curves in the same sense	*242. Minimum length for a straight section between two curves of opposite sense of the plain line*
British Rys	Not specified.	Not specified.
C & O Rys	30 m	30 m
Egyptian Rys	20 m	20 m
Finnish Rys	Two successive curves are combined to a double curve.	40 m
Irish Rys	Not specified.	Provided, if possible.
Japanese Rys *New Tokaido Line*	100 m	100 m
Narrow gauge lines	20 m	20 m
Rock Island Rys	Not specified.	30 m
Seaboard Rys	30 m	30 m
Swedish Rys	$\frac{V}{10}$ m Desirable length $\frac{V}{4}$ m, If possible 20 m	$\frac{V}{10}$ m Desirable length $\frac{V}{4}$ m, If possible 20 m
Soviet Rys	25 m	25 m
T & P Rys	Not specified.	The straight section between two curves is kept as long as possible.

Line on much the same principle. In the case of the New Tokaido Line the following rule is applied, insofar as crossovers with a short straight section between the turnouts are concerned. (In such a case neither transition curve nor superelevation is to exist.)

If the length for a straight section (l) is shorter than the distance between bogie centre pins (L = 19 m), the deviation of car movement will take place in a section represented by $l + L$. This section is taken to be an imaginary transition curve. From experience, the maximum permitted deficiency in superelevation on a crossover is to be taken as 76 mm, and the variation per second of deficiency in superelevation as 57 mm/sec. This is the basis for the rule given in Table 23.

24. *Special layouts.*

Table 24 shows the answers of various countries to Questions 241 and 242.

241. *Do you set a minimum length for a straight section on the plain line between two curves in the same sense?*

Generally speaking, in sections where high speed operation is conducted, it is desirable that car vibration at one end of a curve should be such as to die away before the next curve is reached. For the New Tokaido Line, the minimum length for a straight section on a plain line between two curves is determined from the distance required for the car vibration to die away. In other words, if one period of cycle of the transversal vibration of car is assumed to be roughly 1.5 sec. and the vibration on the first curve normally to die away during one period of cycle, the required minimum length (L) for a straight section will be obtained from the formula

$$L = \frac{1.5\,V}{3.6}\ (m),$$

in which V stands for train speed in km/h.

If, however, the minimum length for a straight section is not obtainable under unavoidable circumstances, a compound curve is put in with a transition curve in between.

242. *Do you keep a straight section between two curves of opposite sense on the plain line, and how do you arrange the superelevation slope?*

The answers from various railways concerning the minimum length of straight section are given in Table 24.

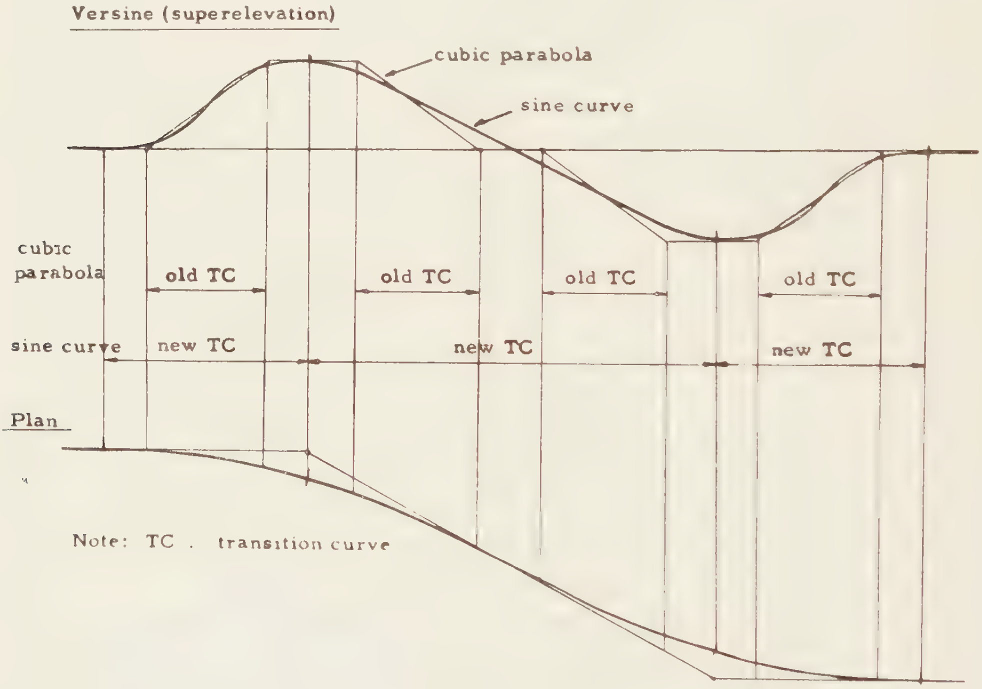


Fig. 243. — Continuous transition curves.

For the New Tokaido Line, the minimum length (L) is calculated as in the case of Answer 241. In cases where the minimum length is not available, the straight section is omitted and a transition curve is applied instead, in such a way that both transition curves will be tangential to each other. This is the case with most railways.

243. *Please give details of any interesting solution you have applied for some special problem.*

One means of making up for the drawback of the existence of a short straight section between two transition curves or of a short circular curve between two transition curves is to eliminate such short straight section or short circular curve, and thereby to create continuous transition curves instead. In this way the transition curves themselves may also be lengthened. This is particularly effective in the case of a reverse curve. Figure 243 shows the example of Japanese Rys. It will be noted that the straight section between opposite curves and circular curve sections are all eliminated by using a transition curve with sine curve for running out superelevation, and the three transition curves are linked continuously to form a reverse curve. Such a reverse curve is effectively made use of when the track is shifted sidewise for the purpose of enlarging the centre-to-centre distance of tracks around a station plaform for example. This curve was used with satisfaction on the section for high speed operation experiment.

25. *Points and crossings.*

251. *What types of crossings do you use on lines operated at high speeds (single piece crossings, crossings with or without noses of special steel, etc.)? In particular, do you require mobile acute or obtuse crossings to be used, i.e. either with mobile frogs or with wing rails worked mechanically or by a spring, and intended to do away with the gap between the nose and the wing rail? Please append a typical drawing of such device.*

Many railways have reported that crossings made of high manganese cast steel seem to be good, when used on lines operated at high speeds. According to the running trials by Japanese Rys, however, when trains pass over the crossings at speeds 130-140 km/h, the transversal thrust, wheel load and vibration acceleration are greater than on other lines. This seems attributable to the fact the wheels run against the part forming a gap between wing rail and nose rail, the guard rail and the wing rail of crossing. As a means of solving this problem the spring crossings of Indian Rys (Fig. 251-1) and Rock Island Rys, and also the movable nose-rail crossings of Japanese Rys (fig. 251-2) may be cited as design examples.

The spring crossings used in Indian Rys and Rock Island Rys are designed to eliminate the gap between wing rail and nose rail of a main line by making the wing rail of branch line movable. The movable nose-rail type of Japanese Rys is designed to eliminate the gap between wing rail and nose rail, therefore, the guard rail on both main and branch lines.

The movable nose-rail type crossing consists mainly, as shown in figure 251-2, of (1) wing rails, (2) movable nose-rail, and (3) crossing block.

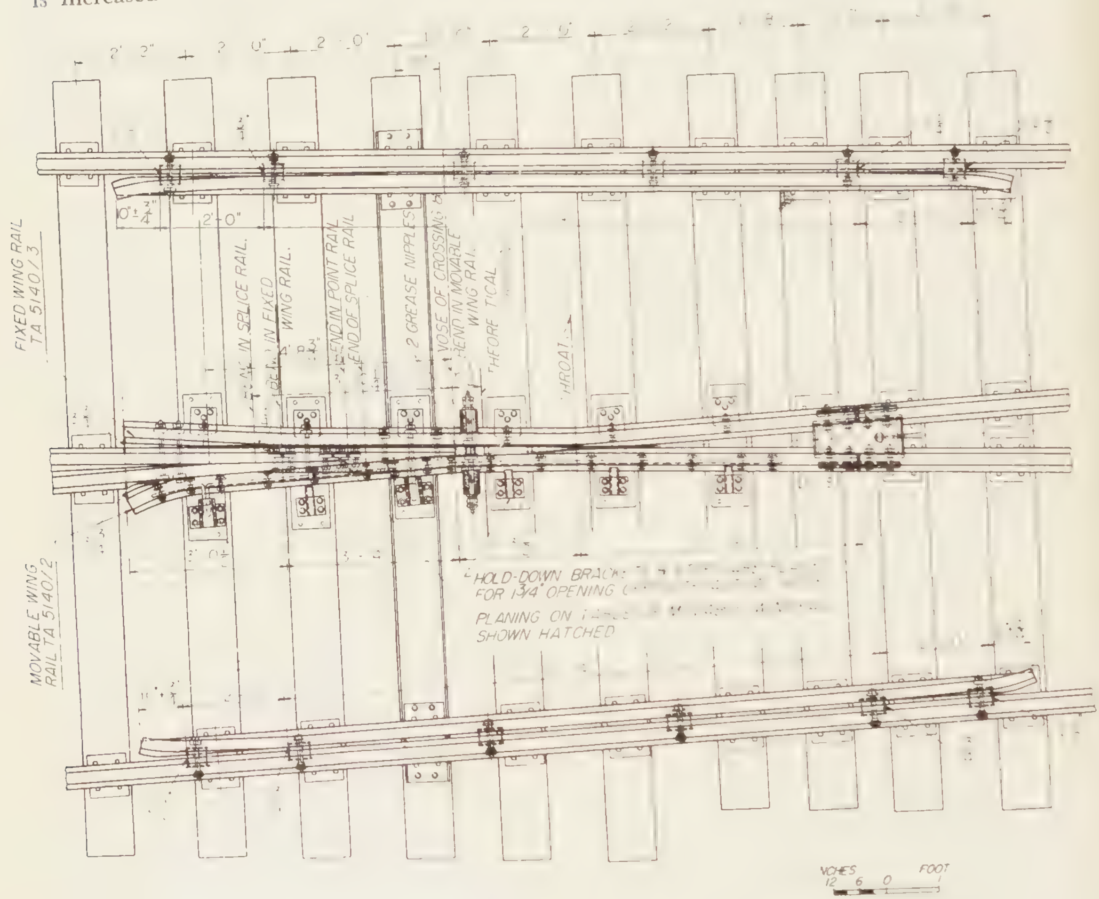
Each of these parts is of manganese cast steel. The toe of the movable nose-rail (2) is closely attached to the wing rail (1) by throwing over the nose-rail. This eliminates the gap between wing rail and nose-rail. The rear part of the movable nose-rail (2) is Y-shaped, and the heel of the nose-rail (2) on the main line forms an elastic part for throwing over the nose-rail, while the heel of the nose-rail (2) on the branch line is so designed as to slide along the crossing block slightly.

This type of crossing is designed for use on narrow-gauge lines. Used on the existing Tokaido Line, it has brought about a good result. The plan is to use this type at all turnouts of the main track of the New Tokaido Line. The expected train speed on such crossing is 200 km/h on the straight side.

252. *What special arrangements do you make to facilitate the running on the main track at high speed (flange ways, protective and guiding or inscription distances, check-rails, wing rails, etc)? Please append typical drawings.*

In designing crossings with a gap between wing rail and nose-rail, the following points are considered by way of improvement :

1) the width of flange ways on both sides is increased so as to avoid impact against be reduced. It is therefore desirable to minimize the allowable difference as far as possible. In some railways no more than 2 mm is approved as such difference. By the same token, care is taken to see that



1 IN 12 LEFT SPRING CROSSING B. G. 90r. F.F.B.S.S.

Fig. 251-1. — Spring crossing.

the wing rail and guard rail. The value ranges from 41 to 48 mm in each country;

2) in order to widen the flange way between guard rail and stock rail as far as possible, the distance between guiding edge of guard rail and nose rail has to be reduced... the difference between the gauge and the distance between outside surfaces of flanges or the so-called play, is minimized;

3) the splay angle of guard rail is reduced as far as possible.

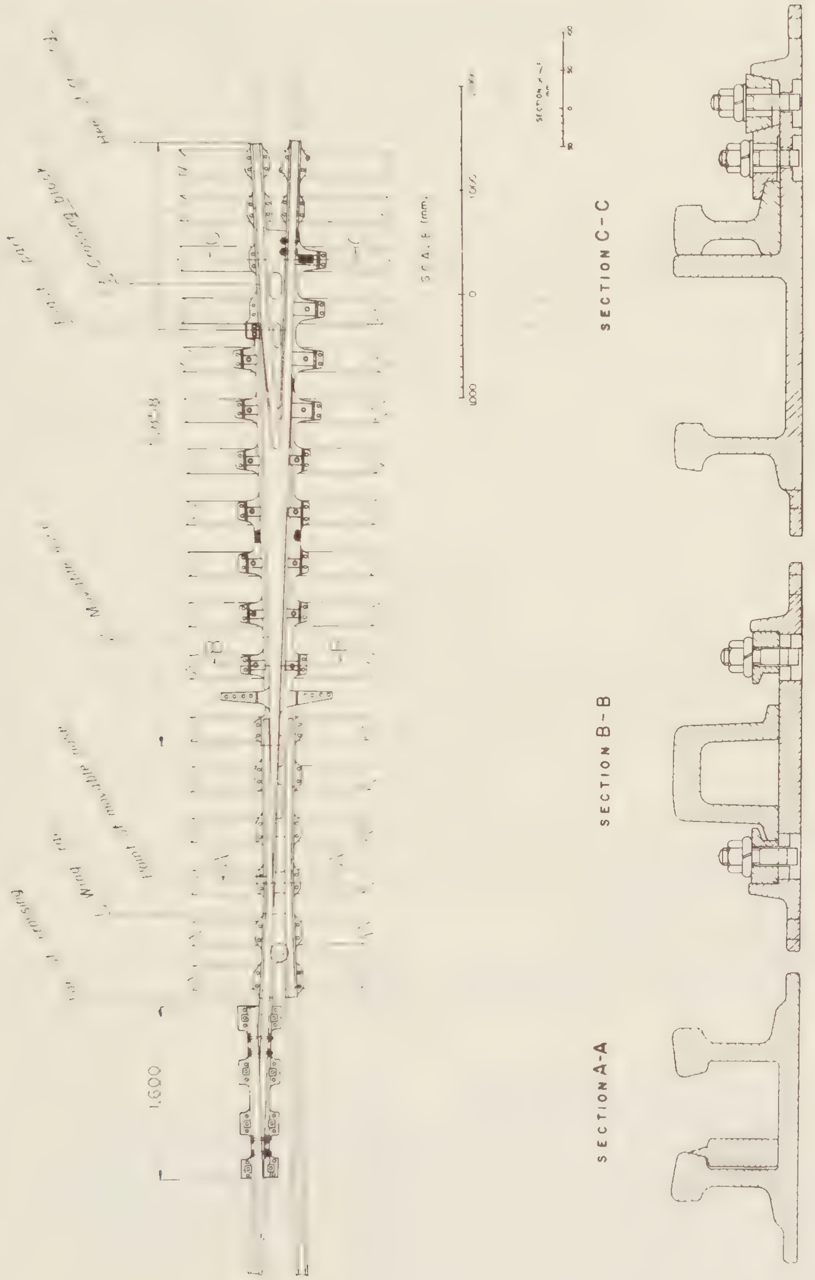


Fig. 251-2. — Movable nose-rail crossing.

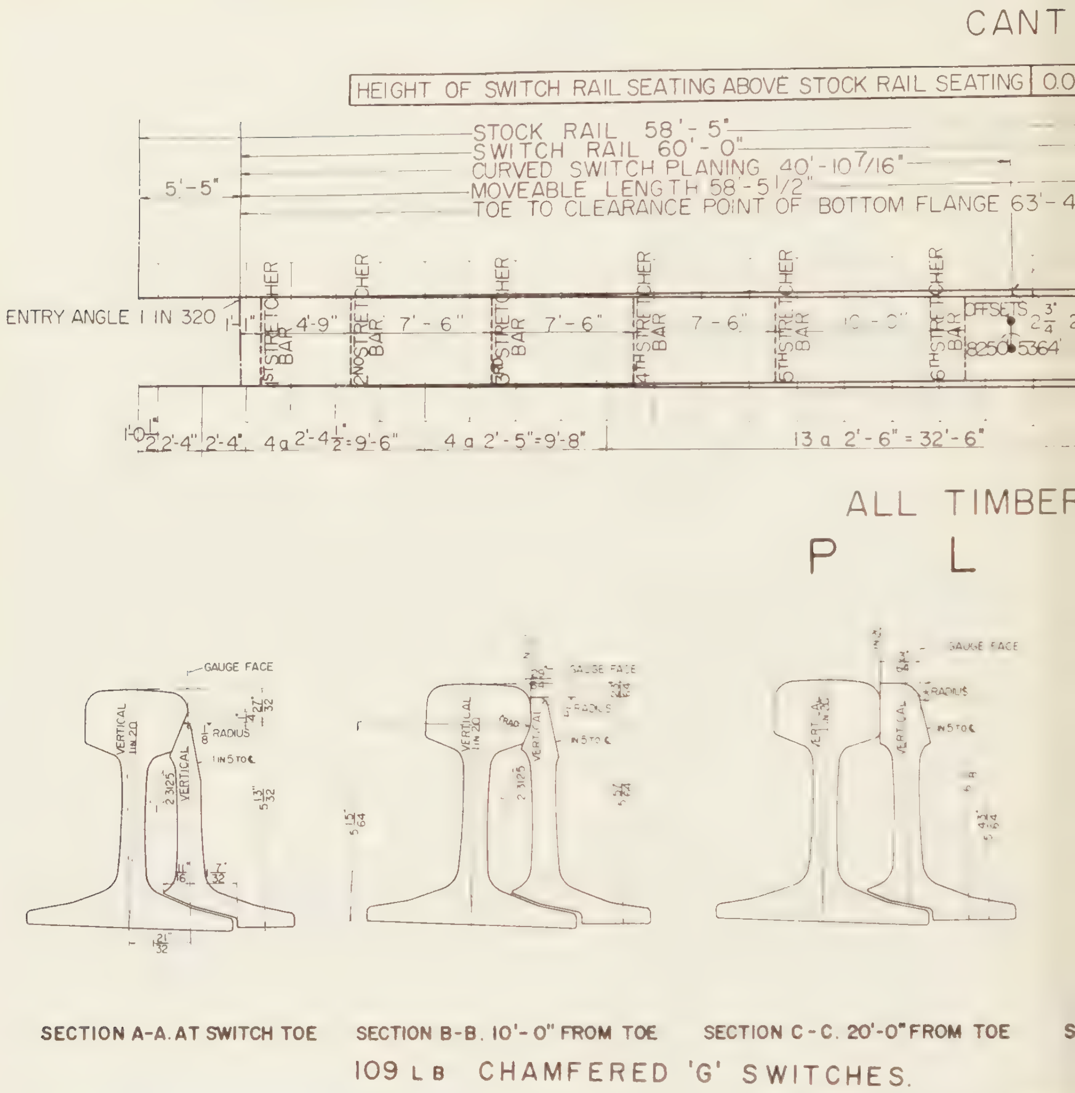


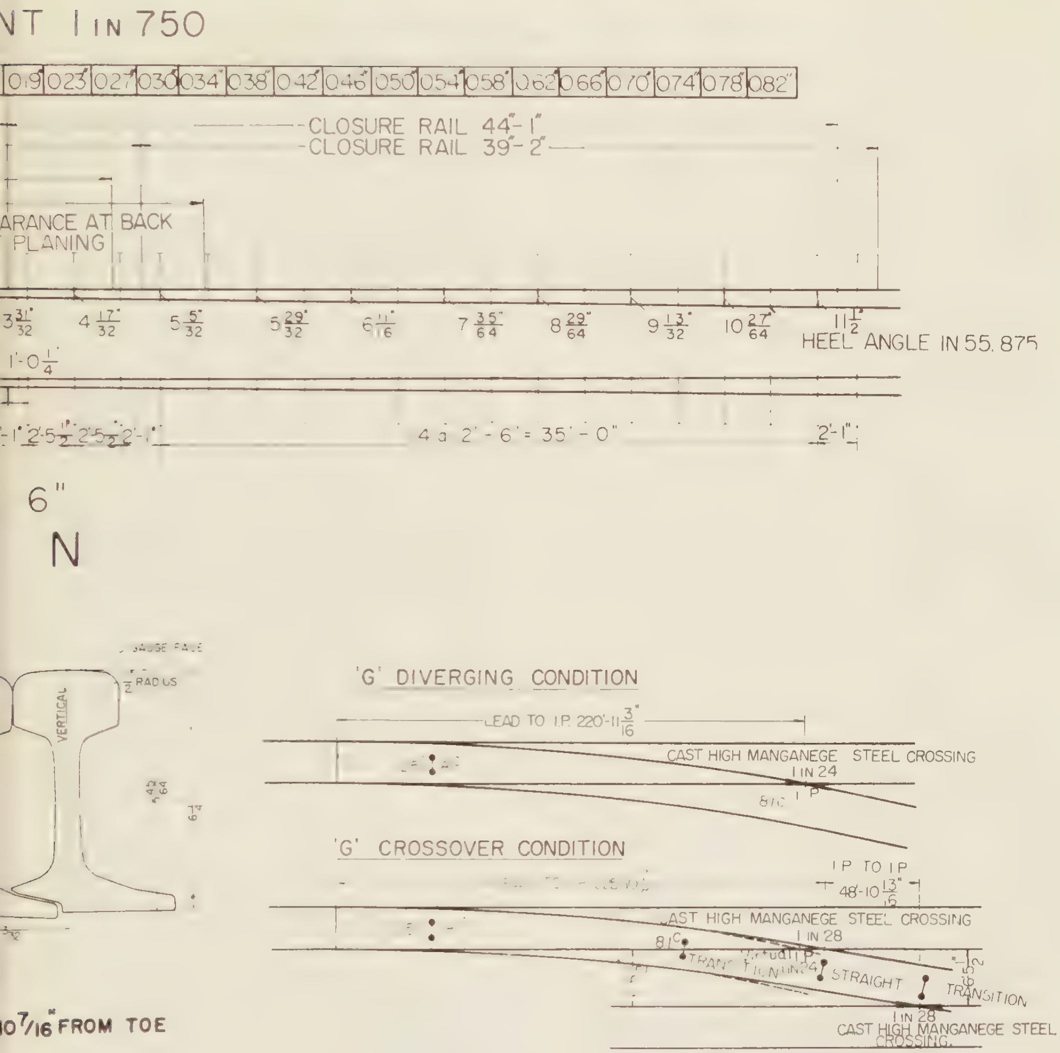
Fig. 255. — Turnout designe

253. *Do you admit diamond crossings with slips on your main lines?*

Such crossings are used in most railways.

254. *To facilitate laying of turnout in a curved main track, do you bend the points and the crossings on manufacture? Do you do this according to a series of typical radii, and if so, how do you adapt in this case the layout of the points and crossings to that of the curved track?*

Many railways use points bent at workshops.



d operation on branch track.

255. *Please give the characteristics of turnouts which can be run through on the branch track at a speed of 120 km/h or 75 m.p.h. or over, as well as those of double junctions and crossovers which can be run through under the same conditions.*

Turnouts which can be run through on the branch track at high speed are designed in British Rys, as shown in figure 255.

26. *Distance between tracks and clearance between tracks and fixed structures.*

261. *What is on your railway, the normal width of the space between two paral-*

lel tracks or the normal distance between centres of parallel tracks? Please make it quite clear how this dimension is measured.

The normal distance between centres of parallel tracks is, where the standard gauge is concerned, 3 405 mm in British Rys, 3 495 mm in Egyptian Rys, 4 100 mm in Finnish Rys, 3 590 mm in Irish Rys, 3 960 mm in C & O Rys, 4 270 mm in Seaboard Rys, 3 970 mm in T & P Rys, 4 260 mm in Rock Island Rys and 4 500 mm in Swedish Rys. The New Tokaido Line is expected to have 4 200 mm; this distance was decided upon from consideration of train wind. Where the narrow gauge is concerned, the corresponding distance is 3 600 mm (gauge 1 067 mm) in Japanese Rys. Where the broad gauge is concerned, it is noted that Indian Rys has 4 725 mm (gauge 1 676 mm) and Soviet Rys, 4 100 mm (gauge 1 524 mm).

262. *What is the minimum distance centre to centre of tracks and under what circumstances does this apply?*

As to the minimum distance between centres of parallel tracks, it is noted that, where the standard gauge is concerned, in Egyptian Rys, Irish Rys, C & O Rys, and the New Tokaido Line, the distance is the same as shown in Answer 261. throughout their respective system; some old double tracks of Swedish Rys have 4 100 mm, some of old tracks of Finnish Rys, 3 800 mm, Seaboard Rys, 3 970 mm, Rock Island Rys, 3 960 mm and T & P Rys, 3 660 mm. Where the narrow gauge is concerned, the freight loading and unloading tracks of Japanese Rys have 3 400 mm. Where the broad gauge is concerned, the old layouts of Indian Rys have 4 265 mm and some of the tracks of Soviet Rys, where baggage is handled directly from wagon to wagon, have 3 600 mm.

263. *What safety clearance do you allow...*

263.1. *Between an obstacle and the kinematic gauge of a vehicle stopping on the inner track of a curve.*

The width of construction gauge on curves has been increased. The safety clearance of Irish Rys is 686 mm and the narrow gauge lines of Japanese Rys, 325 mm. That of the New Tokaido Line is expected to be 415 mm.

263.2. *Between an obstacle and the kinematic gauge of a vehicle running at the maximum speed on the outer track.*

The safety clearance of Irish Rys is 686 mm, and the narrow gauge lines of Japanese Rys, 355 mm. That of the New Tokaido Line is expected to be 445 mm.

263.3. *Between the kinematic gauges of two vehicles, one stopped on the outer track and the other passing at the maximum authorised speed on the inner track?*

The safety clearance of Irish Rys, and the narrow gauge lines of Japanese Rys is respectively 470 mm and 480 mm. That of the New Tokaido Line is expected to be 660 mm.

264. *Taking into account all possible movements of the vehicles (plays and oscillations) and the above mentioned safety clearances, what minimum clearance da you allow...*

264.1. *Between an obstacle and the loading gauge.*

The minimum clearance between an obstacle and loading gauge is 130 mm at 3.5-4.0 m above rail level and 75 mm at 1.12-1.20 m above rail level in Swedish Rys. In Irish Rys the minimum clearance is 610 mm, whereas in Soviet Rys, it is 225 mm at 4.65 m above rail level. That of the narrow gauge lines of Japanese Rys is 290 mm. The minimum clearance of the New Tokaido Line is expected to be 100 mm

264.2. *Between the loading gauges of two trains?*

(These minimum clearances should not take into account any geometrical overthrow of the vehicles beyond the loading gauge centred on the track).

The minimum clearance between the loading gauges of two trains is 500-700 mm in Swedish Rys, 318 mm in Irish Rys 450 mm (at a height of 4.65 m above rail level) in Soviet Rys, and 380 mm in the narrow gauge lines of Japanese Rys. That of the New Tokaido Line is expected to be 600 mm.

265. *Are you considering to increase these safety clearances as speed is increasing?*

It seems that the safety clearance will have to be increased, for the lateral movement and other factors will increase with the increase of speed. But since it is conceivable to construct a car in such a way that is lateral movement may be kept under a given limit, actually it will not be necessary to increase the safety clearance so much, even if the speed is increased. In countries where the safety clearance is already more than sufficient, it is not considered necessary to increase it further.

266. *What do you think about trains crossing each other at high speed, especially in tunnels?*

According to the experiments of Japanese Rys, when trains cross each other out of a tunnel, the wind pressure works first in the direction it makes the cars get away from each other and then in the direction the cars are made to attract each other. Its maximum value makes no difference whether the pressure works in one direction or the other; it is roughly proportional to the square of the relative speed. When the distance between the side of car of one train and that of the other is 600 mm and the relative speed is 200 km/h, then the maximum value of the pressure is 37 kg/m². Where the New Tokaido Line is concerned, the relative speed is expected to be 400 km/h, but since the train is to be streamlined and the side-to-side distance of cars is expected to be about 800 mm the maximum value of the pressure is expected to remain much the same. When trains cross each other in a tunnel, the difference in pressure between the outside of the car and the inside is greater than in the case when the trains cross each other out of it. But model experiments have proved that the transversal pressure is not such as to seriously affect the stability of cars. Therefore, the centre-to-centre distance of tracks is going to be 4.2 m, which is the same as on the normal sections.

27. *Running through large stations.*

Do you impose any speed restrictions on main track lying between two platforms or with a platform on one side?

Most railways have no set any speed restrictions.

28. *Longitudinal profile.*

281. *Do you impose any speed restriction as a function of falling gradients?*

The answers furnished are given in the attached table (Table 281).

282. *When and how do you make vertical curves for transition between changes in gradient? Please give the radius and the practical rules in force.*

The answers are shown in the attached table (Table 282). The value of the vertical centrifugal acceleration depending on the radius of curvature of a vertical curve, when calculated, amounts approximately to 0.01 g-0.4 g.

283. *What do you think about superimposition of a curve in plane and a vertical curve between gradients?*

In Indian Rys the practice is to see that, even in case of superimposition of a curve

TABLE 281. — **Speed restriction of falling gradients.**

	281. Speed restriction as a function of falling gradients		
British Rys	No		
C & O Rys	Yes		
Egyptian Rys	Yes		
Finnish Rys	Restricted in the section of the falling gradient more than 10 ‰		
Indian Rys	Yes		
Japanese Rys New Tokaido Line .	Need not be restricted		
Narrow gauge lines.	*Falling gradient*	*Rate of number of brake axles* 100 %	More than 80 %
	less than 5 ‰	110 km/h	100
	» 10 ‰	105	95
Rock Island Rys . . .	No		
Seaboard Rys	No		
Swedish Rys	*Maximum gradient*	*Trains with sharp braking and railbuses*	*Other trains*
	10 ‰	130 km/h	100 km/h
	12.5	100	90
	17	90	80
	20	60	
	25	40	
Soviet Rys	Restricted in the section of the falling gradient 20 - 30 ‰		
T & P Rys	No		

in plane and a vertical curve, the deficiency in superelevation and the variation per second of superelevation are not excessive. The practice of Finnish Rys, Swedish Rys, and C & O Rys, is to avoid such superimposition as far as possible, and, when it cannot be avoided, to enlarge the radius of curvature of a vertical curve.

Where the New Tokaido Line is concerned, the following method is adopted. On vertical curves on summits, the centrifugal force works upwards, and this, combined with the transversal force, as of wind, is liable to cause cars to overturn. In order to obviate such overturn the superelevation has to be increased by a certain amount, say, (ΔC). Actually, however, this is avoided, since the increase of superelevation by ΔC will affect the design of transition curves. This amount of ΔC is to be added to Cd representing the deficiency in superelevation for the operation of trains of the

TABLE 282. — **Vertical curves.**

	282. *Vertical curves for transition between changes in gradient*
Finnish Rys	$r = v^2$ r : radius of curvature in m v : km/h 15 000 m $< r <$ 25 000 m
C & O Rys	Used where the algebraic difference of intersecting grades is 0.25 % or more at summits and 0.15 % or more at sags.
Indian Rys	Rate of change of grade is not greater than 0.10 % for 30.5 m on summits and 0.05 % for 30.5 m in sags. Rate of change of grade : difference in gradient between successive 30.5 m chords on a vertical curve.
Japanese Rys *New Tokaido Line* .	On straight sections and section where the radius of curvature is not smaller than 4 000 m in plane curve. . . . radius of curvature in vertical curve 10 000 m On sections where the radius of curvature is 3 500 m or less in plane curve. . . . radius of curvature in vertical curve 15 000 m
Narrow gauge lines .	On straight sections and section where the radius of curvature is not smaller than 800 m in plane curve. . . . radius of curvature in vertical curve 3 000 m On sections where the radius of curvature is smaller than 800 m in plane curve. . . . radius of curvature in vertical curve 4 000 m
Rock Island Rys . . .	Vertical curves are made at intersections of gradients. Change of 15 and 31 mm per station is respectively used in sags and on summits.
Seaboard Rys	Changes in grades are connected by vertical curves. The length of vertical curves on summits and in sags is many equal chords as there are respectively one-tenths and half-tenths in the algebraic difference of the grade lines expressed in %. The length of chords is 30.5 m.
Swedish Rys	Used when the difference of gradient is more than 1/1 000. Radius of curvature 15 000 m where V $\geqslant$ 100 km/h.
Soviet Rys	Used when the difference of gradient is more than 3/1 000. Radius of curvature 10 000 m (exceptionally 5 000 m).
T & P Rys	The rate of change per 30.5 m of grade is not to be more than 15 mm in sags and 31 mm on summits.

highest speed on a curve in plane. It is therefore necessary to enlarge either the radius of curvature in plane or of vertical curve, in such a way that the value of Cd + ΔC will be less than the permissible maximum deficiency in superelevation, that is, less than 60 mm. Actually, however, the radius of curvature in plane is mostly unchangea-

ble from the standpoint of its location. The practice is therefore to enlarge the radius of curvature of a vertical curve instead. The following results were obtained from the calculation made by the above method :

if the radius of curvature in plane is 3 500 m or less, the radius of curvature of a vertical curve is 15 000 m; but if the radius of curvature in plane is 4 000 m or more, the radius of curvature of a vertical curve is 10 000 m.

29. *Track over steel bridges.*

291. *Do you consider a steel bridge to be an obstacle to high speed running?*

Since, in high speed operation, the vibration of cars increases due to the rocking motion and other factors, this has to be taken into consideration in design load. The following points were studied in regard to the New Tokaido Line where operation at a speed of 200 km/h is expected :

1) limit of vertical or transversal deflection of girder of bridge.

When two girders are laid on a pier, a deflection angle occurs at each girder end on account of the deflection of girder due to a car load. As a principle, therefore, the track level would became somewhat pyramid-shaped, but as a matter of fact the track level forms a vertical curve for the rigidity of rail. In the case of a ballasted bridge, however, the vertical curve thus caused becomes so gentle as to enlarge the radius of curvature. If the limit of vertical deflection is to be calculated on the assumption that the vertical centrifugal acceleration does not impair the riding quality when a train passes over the vertical curve at a speed of 200 km/h, it will be about 1/1 800 of a span. Therefore, the limit of vertical deflecion of steel bridges of the New Tokaido Line is fixed at 1/1 800.

In conducting high speed running tests (at a speed of 160 km/h), the girders picked out for the tests were lifted at the centre pier, so that the angle formed by the two girders on that pier would reach 6/1 000 rad. As a result, a small vertical curve was partially formed there. The vertical car vibration acceleration measured on the pier on that occasion was 50-90 % greater than in normal sections.

Similarly transversal deflection may be calculated on condition that the transversal centrifugal acceleration does not impair the riding quality when a train passes on the pier. The amount of transversal deflection thus calculated will reach about 1/3 600 of a span in the worst condition. For this reason the limit of transversal deflection of steel bridges of the New Tokaido Line is fixed at 1/3 600;

2) limit of skew angle of skew bridge.

When a train passes over a skew bridge the cars roll, because, near the girder end the extent to which one wheel goes down on account of the girder deflection does not concur with that in the case of the other wheel on the same axle.

When such a roll occurs on a skew bridge, the limit of the skew angle, if calculated on condition that the transversal car vibration acceleration does not impair the riding quality, will be 45° or thereabout. Therefore, the limit of the skew angle of steel bridges of the New Tokaido Line is, as a rule, fixed at 45°;

3) special structure on back of abutment.

Care is taken to see that subgrade construction is as free from any danger of sinking as possible. Where the subgrade is weak and is liable to sinking due to consolidation, it is considered unavoidable that an accumulated settlement amounting to about 50 mm should occur during the first year. The abutment itself does not sink because the foundation work is done with the utmost care. But the banking at back of the abutment is liable to go down and give rise to irregularities. As a result, this particular spot, and not other parts, requires very frequent operation of levelling.

The following device is taken to make good this drawback (fig. 291).

This is the use of a concrete beam one end of which is placed on the abutment that

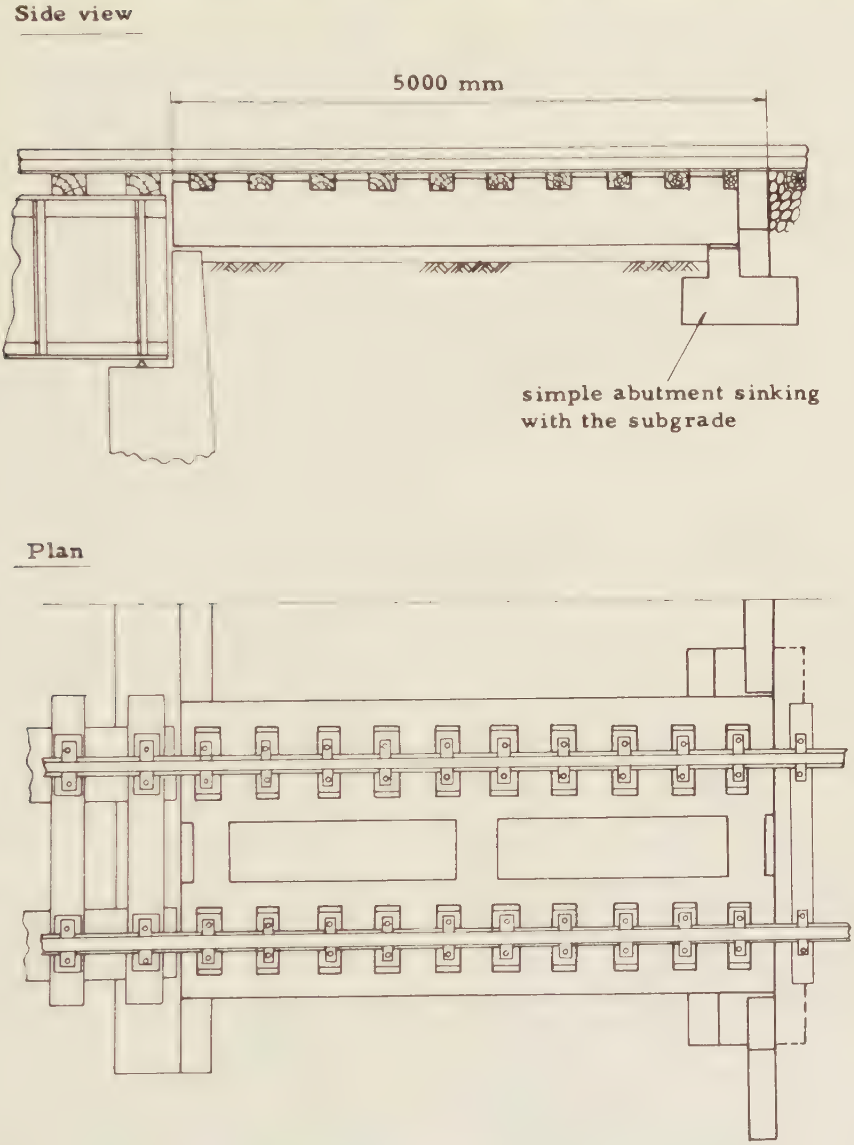


Fig. 291. — Special structure on back of abutment.

will not sink and the other end on the simple abutment that will sink with the subgrade. The use of this sort of beam leads to alleviate the variation in longitudinal level per meter by as much as the length of the beam, and the period of maintenance work will thus be prolonged. Moreover, the operation of lifting tracks, too, can probably be performed easily by using packings at the support of the beam which will sink.

292. *Does the camber normally given to the deck of a bridge give rise to new problems from the point of view of high speed running?*

Many railways are of opinion that the camber does not pose new problems. It is desirable for train running that the track surface should be level when there is a live load on it and otherwise be convex shaped, but actually the bridge deflection due to live load is generally not so great as to demand special consideration on this point. For this reason most railway bridges are cambered in such a way that the track surface will be level when there is no live load on it.

293. *Have you adopted any special arrangements for the track laid on steel bridges? Is this only done in the case of high speeds?*

It is desirable that elastic fastenings and long welded rails be used for the track laid on steel bridges, in order that high speed operation may be performed almost as smoothly as in sections other than bridges. Supposing the track to be used for steel bridges with ballast is similar to one used for other ballasted sections, the difference, if any, in thermal expansion and contraction of rail and girder will be absorbed, it is considered, by the displacement in the ballasted portion, provided long rails are used. In the case of steel bridge on a long rails section without ballast, however, where the rails and girder are directly connected, with sleepers or rubber pads in between, the following consideration has to be given :

in the case of a bridge existing in the central part of long rails, the rails do not move as a result of temperature variation, but the girders expand and contract almost freely. If, therefore, the resistance of rail fastenings on the bridge section to the longitudinal movement of rail increases, the reaction force to the abutment and the axial force in rail also increase. When more than one span of girders are used, with the fixed end of one girder and movable end of another located on each pier, i. e. all the girders expand or contract in the same direction, such forces increase with the increase of the number of girders and, as a result, the long rails will find themselves in danger of buckling or being ruptured through excessive axial force.

If the value of resistance of rail fastenings is reduced over a long section, then the extent of rail rupture, if it should occur, will grow greater. This drawback may be made good by using expansion joints at both ends of each girder. The thing is to use as few expansion joints as possible. With this in mind, Japanese Rys is contemplating to adopt the specifications as shown in the accompanying table (Table 293).

The tabulated figures are based on the assumption that, when the girder is in a long rail section, the axial force put on the long rails by the thermal expansion of girder is such as to free long rails from buckling or being ruptured and that, in case of rail rupture, the extent of rupture does not exceed 50 mm. It may be added that the expansion joint allows a movement of ± 100 mm at either end of a long welded rail.

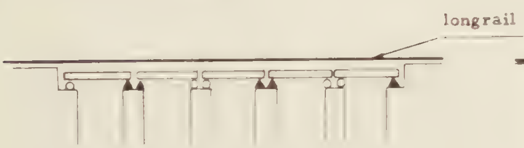
294. *Do you consider that curved track on bridges gives rise to any special difficulty?*

On curves in sections intended for superhigh speed operations, increase in centrifugal force reaches a value approaching 20 % of vertical load. The question is, therefore, whether the girders should be installed level or they should be inclined. If a bridge is to be built level, with the superelevation created on the superstructure of track, the disadvantage of the design is that there is a fair difference in the load to be borne by the right and the left main girder (Indian Rys). Then again the transversal deflection already mentioned has to be taken into consideration. Furthermore, in the case of deck girder bridges, the disadvantage is that the direction of the resultant force of centrifugal force and vertical load is off the centre line of girder (Indian Rys). In the

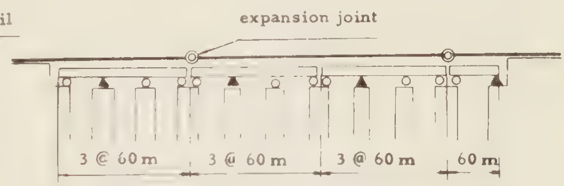
TABLE 293. — **Long rail on steel bridge.**

Type	*Girder length*	*Bridge length*	*Expansion joint*	*Bridge seat*	*Range of resistance of fastening on girder against creep*
Non-ballasted girder	Less than 60 m	Less than 60 m	None	No restriction	0 t/m/1 rail
	»	60 m — 100 m	None	Movable ends of two girders are laid on one pier; and fixed ends of two girders on another pier. * 1	0.4 - 1.2 rail
	»	100 m or more	None	» * 1	0.6 - 1.2 rail
	60 m or more	60 m or more	Necessary	Bridge seats are arranged in connection with the position of expansion joints case by case * 2	0.2 - 0.5 rail
Ballasted girder				Same as ordinary ballasted track	

* 1 *Example 1*



* 2 *Example 2*



Note: o movable support

▲ fixed support

case of a bridge with sleepers but no ballast, a special device has to be provided so as to give a superelevation (Soviet Rys).

Then there is a case of installing girders slanting in proportion to the superelevation. In this case, when a train passes the bridge at a balancing speed, the transversal force caused by centrifugal force will not only work on the girders, but it will eliminate the necessity of providing a special device for the superelevation, even if the sleepers were used without ballast. On the other hand, however, it will render the work of installing girders rather cumbersome and will necessitate attention to the drainage of the bridge members. Generally speaking, straight girders are built even in curved sections. It is necessary, however, to con-

sider in what position the centre line of girder should be placed against the centre line of curved track, in order that the load on the right and left main girders may be equalized.

Where the New Tokaido Line is concerned, the deck girders are to be installed with an inclination of about 80 % of the superelevation and the centre line of girder is to be located 1/6 of the versine in an arc, of which the length of girder forms the chord, shifted inwards from the centre line of track at the centre of girder span.

3. Constitution of the permanent way.

31. *Statistical information.*

Please fill up the annexed Table No. 31.

See Table 31, Statistical Data Concerning the Equipment of the Lines, at the end of this report.

32. *Speed restrictions.*

Do you impose any speed restrictions on the trains as a consequence of following factors :

321. *Type of rail.*

In general, speed restrictions are independent of a type of rail.

322. *Weight of rail (what is the weight in normal conditions).*

Since the track becomes more liable to destruction as the train speed increases, it is advantageous to use heavier rails in order to enable the track to resist such a destructive force. It should be noted that many railway administrations use rails about 50 kg/m or more on sections where they operate trains at a high speed (see Table 31).

323. *Length of rail.*

Impact on rail joints is a big cause of deterioration of a track. The intensity of impact is considered to increase with train speeds. Therefore, the longer the rail is, the easier is the track maintenance, particularly where trains are operated at a high speed. Long welded rails are being laid on lines of high speed operation in the countries which submitted their report (see Table 31).

324. *Kind of sleepers.*

324.1. *Soft wood.*

(Please give details concerning the methods of reinforcing them, conditions under which they are used ,etc...).

Soft wood sleepers are considered liable to decay, cutting-in of rail and split, but wooden sleepers of certain species are used on sections of high-speed operation by reinforcing them with tie-plates, steel bands and treating them with a preservative.

324. 2. *Reinforced concrete.*

Reinforced concrete sleeper has the problem of cracks occurring on its surface. Therefore it is not much used as an ordinary cross sleeper, though it is sometimes used on high-speed lines in the form of blocks of smaller length, such a two-block sleeper.

324.3. *Prestressed concrete.*

Compared with a wooden sleeper, prestressed concrete sleeper has a greater strength and longer span of life and can be mass-produced, and it is used on lines of high-speed operation in many countries (Sweden, Japan, etc.).

324.4. *Steel.*

Though used in Egyptian Rys, Indian Rys, etc., a steel sleeper is not generally much used (see Table 31).

325. *Sleeper arrangement (No. of sleepers per km or per mile) ?*

Spacing of sleepers varies according to the type of sleepers, characteristics of the

rolling stock used and the strength required of tracks. It is observed that, for the high-speed operation of trains, sleepers are arranged at a rate of between 1 500 pieces and 1 800 pieces per km in most countries. Some railway administrations use broader sleepers of a larger size, spacing them at about 1 300 pieces per km (see Table 31).

33. *Equipment of the permanent way.*

331. *Use of long rails: what is the minimum radius allowed according to the kind of sleeper?*

The minimum radius allowed for tracks laid with long rails in Swedish Rys and Japanese Rys is 1 000 m, and that in British Rys and Egyptian Rys is 800 m, while Indian Rys use long rails on straight sections only. The generally accepted limit against buckling due to temperature rise is 500 to 600 m.

The track with concrete sleepers is considered to resist buckling better than the track with wooden sleepers. But, at present, long rails are not laid on such sharp curves. Therefore, most railway administrations do not specify different minimum radii of curvature for concrete sleepers and wooden sleepers.

332.1. *Use of short rails: do you use opposite, alternating, or staggered joints? In what cases do you make use of each such method?*

Most railway administrations use opposite joints, but railways in the United States and Australian Rys use staggered joints more. Staggered joints are sometimes used on curves in Indian Rys, Irish Rys, Japanese Rys, etc. Respective track lengths for opposite joints are staggered joints are listed in Table 31.

332.2. *If you use staggered joints, by what amounts are they staggered and what are the tolerances allowed in this connection?*

In any railway administrations which submitted report, a rail joint faces opposite to the middle part of the rail of the other side where staggered joints are used. The tolerances allowed are 1 m in Egyptian Rys, 30 cm in Indian Rys, 90 cm in C & O Rys, a quarter of the rail length in Japanese Rys, 61 cm in Rock Island Rys and 61 cm for straights and 122 cm for curves in Seaboard Rys.

333.1. *What kind of fastenings are used? Characteristics as regards tightness and deformation of the elastic parts.*

Many railway administrations have reported that they use elastic fastenings in most cases where trains are operated at a high speed. The practices of the railway administrations submitted report are summarized in Table 333.1.

Characteristics required of fastenings on tracks for high speed operation are resistivity to lateral force and dissipation of impact received. To raise the resistivity to lateral force, a method of distributing the lateral force to several sleepers making the fastening laterally elastic, is conceivable (101-type fastening of Japanese Rys, for example) in addition to the method of increasing the lateral strength of the fastening itself. To mitigate the impact, the rubber pad or other shock absorbers to be laid under the rail may be made softer. But a very soft pad would call for the rail clip spring to be made soft enough to match it, and moreover, as it would make it difficult to transmit lateral force from the rail to the sleepers, designing of a good fastening would then become a difficult problem. Therefore, in usual practice, the spring constant of rubber pad used at present is 100 to 200 t/cm and that of rail clip spring is 1 to 2.5 t/cm.

333.2. *What rules govern the use of chairs or base-plates in connection with the importance of the line and the curvature?*

Wooden sleepers are equipped with tie-plates of one type or another, whether on straight or on curved sections.

TABLE 333.1 — **Fastening**

Railway	*Type of fastening*	*Remarks*
Egypt	Direct fastening (saddles and screw spikes) Indirect fastening (tie-plates, clips and bolts)	Re-tightening is required from time to time.
Finland	Tie-plates and cut spikes or spring spikes Norwegian Hey-Back German K-Fastening	mainly for 43 kg/m rail for 54 kg/m rail for 54 kg/m rail
India	Dog spikes and round spikes (wooden sleeper) Two-way keys (steel sleeper)	
Ireland	Through-bolt fastening with tie-plates or chairs	
Japan *Narrow gauge lines* *New Tokaido Line*	F-type tie-plates (wooden sleeper) with plate springs and rubber pads (110 t/cm) 3-type (concrete sleeper) with plate springs and rubber pads (110 t/cm) 301 type tie-plates (wooden sleeper) with plate springs and rubber pads (90 t/cm) 101 type (concrete sleeper) with plate springs, rubber pads (90 t/cm) and lateral springs (15 t/cm)	initial force 0.5 t piece spring constant 1 t/cm initial force 0.5 t/piece spring constant 2.2 t/cm initial force 0.5 t/piece spring constant 0.6 t/cm initial force 0.5 t/piece spring constant 0.6 t/cm
Soviet Union .	Tight dog spikes (wooden sleeper) Separate semi-elastic fastening and tight elastic fastening (concrete sleeper)	There are two types, one used with tie-plates, the other without. Both are the double elastic fastenings that use rubber pads.
Sweden	Rueping type elastic spikes (wooden sleeper) Hey-Back type plate springs (wooden sleeper) Fist type spring bars (concrete sleeper)	initial force 0.5 t/piece initial force 0.7 t/piece spring constant 1 t/cm initial force 2 t/set spring constant 2 t/cm
T & P	Double shouldered tie-plates, cut track spikes and anti-creeping devices	

334.1. *What types of fishplates are used? Please append details if special types are used.*

Fishplates of bar type are used. It is difficult to make the vertical geometrical moment of inertia I_x at the joint nearly equal to that of the middle part of a rail. At present, it stands at about 30 or 35 % of the I_x of a rail.

334.2. *Is the joint supported or suspended?*

Suspended joint is predominantly used. Supported joint is used on some sections of Swedish Rys, railways in the United States, Japanese Rys, etc.

335. *Do you take any special precautions against rail creep in braking zones (short rails, long rails)?*

In most countries anti-creepers are used where necessary. Some railway administrations, such as Finnish Rys, Irish Rys, Japanese Rys and Swedish Rys, are of the opinion that anti-creepers are not necessary since the elastic fastening is effective enough to hold rails fast against creeping.

336. *Is the equipment as described above satisfactory in the case of very high high speeds?*

Most railway administrations have reported that their best track equipment in service can safely withstand super-high speed operation of trains.

Swedish State Rys have reported that trains can be operated a super-high speeds if the axle weight does not exceed 20 t and if Hey-Back or Fist fastenings are used. Generally, judgement of whether or not a track can stand super-high speeds must be based not only on such factors as safety and riding comfort of trains, but also on whether or not the destruction of track by high speed trains is within an economically allowable limit. In designing tracks for the New Tokaido Line of the super-high speed operation at 200 km/h, Japanese Rys had to study how much the track would be deteriorated, whether it could be maintained and what sort of track structure would be economical with maintenance cost taken into account. The following study was made to calculate the destruction of tracks before they could decide on the track structure to be adopted. The outline of the study is given below:

The external force L to destroy a track (interpreted here as a force to cause ballast sinking or deformation) is considered to be proportional to the passing tonnage, train speeds and the coefficient of the characteristics of rolling stock as stated in Answer 142. To lessen the destruction of track by the external force, the track structure should be strengthened by various methods, such as enlarging the rail section, increasing the ballast depth and so on. Let the coefficient for the strength of track structure be named track structure coefficient M (value is smaller, as the track structure becomes stronger), and the amount of destruction of tracks will be expressed by L $\times$ M. As it is considered that the amount of destruction of tracks (amount of sinking of ballast) is proportional to the ballast pressure P_b and the vibration acceleration of ballast $\ddot{y}$, M will be expressed as $sP_b\ddot{y}$ where s is a coefficient which is related to the impact varying with the types of track structure. In the equation $M = sP_b\ddot{y}$, P_b is given as a value obtained by dividing the maximum load under rail-seat on a sleeper by half a sleeper footing area. $\ddot{y}$ and s are given by the formulae in Table 336, based on empirical values and theoretical review.

Once L and M are determined as stated above, the amount of destruction of various types of track structure can be computed. For example, let us take a standard track structure, as given by the right hand column in Table 336, on which existing rolling stock run at 100 km/h and which is duly maintained by usual maintenance practices, and compare it with a newly designed track structure of the New Tokaido Line for which rolling stock characteristics, gross tonnage operated, train speeds and so on are given in another column in the same Table. According to the calculation shown in Table 336, the external destructive force L of the new track is twice the value for the standard track, because the gross tonnage is 1.3 times as big and the train speed is twice as high, although the rolling stock characteristics are improved. The value of M for the new track is 0.6, being smaller because the track structure is made stronger. Therefore, the amount of destruction of the new track is calculated as $0.6 \times 2 = 1.2$. In other words, the new track will be 20 % more liable to destruction than the standard track.

In designing the track for the New Tokaido Line, Japanese Rys applied various combinations of rails, sleepers, pads, ballast depth, etc., and the extent of the destruction of each type of tracks was calculated as explained above. Then, maintenance cost (number of gangs, equipment, and so on) as induced from the amount of the des-

TABLE 336. — **Calculation of destruction of track.**

	Item of computation			*Track of the New Tokaido Line*	*Standard track*
Load coefficient	Rolling stock characteristics ratio			0.77	1
	Gross tonnage ratio			1.3	1
	Speed ratio			2.0	1
L	Ratio of L			2.0	1
Track structure coefficient M	Track structure	Rail	kg/m	53.0	50.4
		Sleeper (prestressed concrete) Type		2 Ta	PC-2
		Sleeper Spacing (a)	cm	60	58
		Sleeper half a sleeper footing area (B)	cm^2	2 300	2 240
		Pad Spring constant (D_1)	t/cm	90	100
		Ballast Depth (d)	cm	30	25
		Ballast modulus (C)	kg/cm^3	20	16.7
	Ballast pressure (wheel weight 1 ton)	Ballast depression modulus $D_2 = BC$	t/cm	46	37.3
		Spring constant of the rail support $D = \frac{D_1 D_2}{D_1 + D_2}$	t/cm	30.4	27
		Maximum load under rail-seat on a sleeper P	t	0.368	0.372
		Maximum pressure on the ballast immediately under the sleeper $P_b = \frac{P}{B}$	kg/cm^2	0.161	0.167
	Vibration acceleration of ballast	Support mass (m)	kg	607	404
		Vibration acceleration $\ddot{y} \propto \sqrt{D} \cdot \frac{1}{\sqrt{m}}$		39×10^{-2}	50×10^{-2}
	Shock factor	Spring constant of the rail support divided by the sleeper spacing $K = \frac{D}{a}$	kg/cm^2	506	466
		Rigidity of rail (EI_x)	kg/cm^2	479×10^7	366×10^7
		$\beta = \sqrt[4]{\frac{K}{4 EI_x}}$	cm^{-1}	1.28×10^{-2}	1.34×10^{-2}
		Shock factor $s \propto \frac{1}{EI_x \beta^2}$		1.29×10^{-6}	1.62×10^{-6}
	Track structure coefficient	$M = P_b \cdot \ddot{y} \cdot s = P_b (\sqrt{D_1} \frac{1}{\sqrt{m}}) (\frac{1}{EI_x \beta^2})$		810×10^{-10}	$1\,347 \times 10^{-10}$
	Ratio of M			0.60	1
Ratio of degree of destruction of track L × M				1.2	1

truction of each type of track was calculated. Finally, decision was made on the adoption of such type of track structure and maintenance system as would minimize the total sum of the annual capital cost (depreciation expense and interest on investment) and annual maintenance expenses.

337.1. *What is the normal gauge on laying? Does it vary with the type of sleeper?*

Finnish Rys lay rails on a gauge of 1 522 mm against the specified gauge of 1 524 mm, as far as 54 kg/m rails are concerned. Swedish Rys fix their gauge at 1 433 mm as against the standard gauge of 1 435 mm. Other railway administrations do not vary the gauge on laying.

337.2. *What inclination is given to the ra'' to the rail on the plain line and at points and crossings?*

An inclination of 1/40 is adopted by some American Rys (C & O, Rock Island, Seaboard and T & P), Finnish Rys (in the case of 54 kg/m rails) and Japanese Rys. Swedish Rys adopt 1/30 and most of other administrations specifiy 1/20. As regards the relationship between the inclination of tyre and the rail inclination, Swedish Rys adopt 1/20 for the former and 1/30 for the latter. Japanese Rys adopt 1/20 and 1/40, respectively, for their narrow gauge tracks. Other railways mostly use 1/20 in the cases of tyre inclination and rail inclination. Many railway administrations do away with rail inclination at points and crossings.

British Rys give an inclination of 1/20 to rail at points and crossings, and Japanese Rys plan to use 1/40 for the New Tokaido Line.

337.3. *What is the maximum and minimum play of a set of wheels on the track and what is the influence thereof on rocking motion?*

The maximum and minimum play of a set of wheels adopted by each railway administration is given in Table 337.3-1. It is within the range of from several mm. to 40 mm.

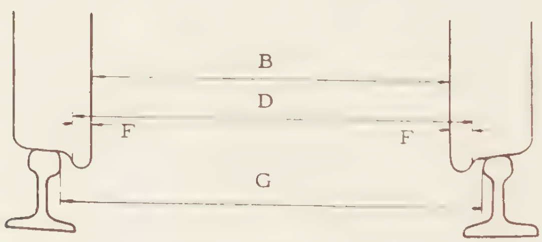
TABLE 337.3-1 — **Play of wheels on track.**

Railway	*Minimum or Standard* (mm)	*Maximum* (mm)	*Remarks*
Britain	16		When rail and tyre are new.
C & O	21		Normal gauge difference.
Egypt	4.8		
Finland	10	28	The maximum value representing the case of maximum worn flanges.
India	19	44.5	The standard value representing the case of new rail and tyre.
Seaboard . . .	13	25	
Sweden	4	20 31 37	When gauge is at the minimum, 1,430 mm. When gauge is at the maximum, 1,441 mm (straight). When gauge is at the maximum, 1,447 mm (curve).

The plays of a set of wheels as computed by the Japanese Rys for the New Tokaido Line and existing narrow gauge lines are shown in Table 337.3-2.

TABLE 337 .3-2 — **Play of wheels on track in Japan.**

	Japanese Rys	
	Standard gauge (New Tokaido Line)	*Existing narrow gauge*
Distance between the interior surface of flanges B Difference Δ B	1 358 — 1 360 2	988 — 994 6
Distance between the outside surface of flanges D Difference Δ D	1 412 — 1 426 14	1 032 — 1 054 22
Thickness of flange $F = \frac{D - B}{2}$ Difference Δ F	26 — 34 8	19 — 33 14
Track gauge G Difference Δ G	1 433 — 1 440 7	1 063 — 1 074 11
Play $u = G - D$ Difference $\Delta y = \Delta D + \Delta G$	7 — 28 21	9 — 42 33



337.3-2.

If the play is excessive, it will augment the amplitude of rocking motion and affect the smooth travelling of wheels at points and crossings and at expansion joints. From such consideration, Japanese Rys have decided to adopt a shorter play for its New Tokaido Line than that for the existing narrow gauge lines.

34. *Ballast.*

341. *What type of ballast is used on high speed lines?*

Most railway administrations agree that high speed lines had better be laid with crushed stones with higher resisting force against loosening and sinking, since ballast

becomes more liable to depression as the train speed increases. According to experiments made by Japanese Rys by use of the load repeating ballast testing machine, screened gravel lacking edges sinks conspicuously faster than crushed stone. When comparison is made between the crushed stone ballast of river bed boulder and that of mountain rock, the former with less edges than the later, becomes loose and depressed definitely in a shorter time.

As regards the quality of the stone, strenght and anti-abrasive characteristics should be most desirable. It is also desirable that too flat or too long particles do not commingle.

342. *What grading of ballast is used? Does this vary according to the kind of sleeper or method of lifting?*

Grading of ballast adopted by the various railway administrations is shown in Table 34. In general, the maximum diameter is 50 to 60 mm and the minimum is 10 to 30 mm. The maximum diameter of ballast does not vary according to the kind of sleeper in most countries, but in some countries (Britain, India, etc.) different diameters are specified according to the kind of sleepers. In levelling a track by means of shovel packing, most railway administrations use small sized particles ranging between 10 and 30 mm.

Tracks for high speeds must be constructed and kept corrected with high degree of accuracy. Therefore, it may be preferable to use crushed stone of somewhat smaller size insofar as concerns the portion of ballast supporting the sleeper. Some railway administrations use crushed stone of small diameter in specific positions, such as turnout and expansion joint, where higher accuracy is required in maintenance.

According to the experiment conducted by Japanese Rys on the relationship between the size of grain and the sinking of ballast, the speed of loosening and sinking of ballast due to vibration does not so much differ by grading and grain size, within the range of 10 to 50 mm.

343. *What depth of ballast do you require under the sleeper for the ballast itself and for the layer of sub-ballast? Does this vary according to the importance of the line?*

The depth of ballast and sub-ballast specified by the various railway administrations is shown in Table 34. Generally the ballast itself is specified at 200 to 300 mm and the sub-ballast at 100 to 200 mm.

The minimum depth of crushed stone needed for levelling by means of tamping is considered to be about 200 mm. However, in order to uniformly distribute the pressure which works on road bed and thereby lessen the road bed surface pressure, total ballast depth including sub-ballast under the sleeper will have to be 400 to 600 mm, though it depends on loads, track structure and the strength of road bed formation.

344. *What is the level of the ballast between the sleepers?*

The ballast level between the sleepers, as adopted by the various railway administrations, is shown in Table 34. To effectively prevent long rails from buckling, some railway administrations lay the ballast higher than the sleeper level at the ballast shoulders.

345. *What is the minimum width of the shoulders* with short and long rails, with wood, concrete and steel sleepers?*

**Distance from the ridge of the ballast slope to the outer edge of the nearest railhead.*

The minimum width of the ballast shoulders adopted by the various railway administrations is shown in Table 34. Where long rails are laid, the ballast shoulders must be wide enough to prevent buckling due to a rise of temperature.

346. *What is the width of the formation outside the ballast layers and its level below the top of the rails?*

TABLE

	Question	British Rys	C & O Rys	Egyptian Rys	Finnish Rys	Indian Rys
342	Grading of ballast		12 - 43	20 - 60 20 or less for lifting	30 - 60	Maximu diamete Woode sleeper 51 Steel sleeper 38 Points a crossing 25
343	Depth of ballast : Ballast itself. . . . . Sub-ballast	305	300	250 150 - 200	300 150	254
344	Ballast level between sleepers. (below sleeper top)	25	50	20 - 40	20	Sleeper t
345	Width of ballast shoulders . . (distance from ridge of ballast slope to rail head).			1 000	870	Short ra 762 Long ra 864
346	Width of formation . . . . . (outside ballast layer)	Embankment 1 219 Cutting 990		650	450	1 041
	Formation level outside ballast layer below top of rail. . .	610	750	600	650	470

The numerical data obtained from the various railway administrations are given in Table 34. Some of the railway administrations use the width of 1 m for workers' passage. The level is about the same as the bottom of ballast slope in most countries.

4. Renewal of the permanent way.

41. *Plain line.*

Renewal of the permanent way normally includes the following operations :

removal of ballast;

t.

Unit : mm

Irish Rys	*Japanese Rys*		*Rock Island Rys*	*Seaboard Rys*	*Soviet Rys*	*Swedish Rys*	*T & P Rys*
	Narrow	*Standard*					
	10 - 60	10 - 60		10 - 30		30 - 60	19 - 38
100	250	300	100 - 200 150 - 200	150	250	240 90	150 - 250
per top	Sleeper top	Sleeper top	Sleeper top	Sleeper top	30	Sleeper top	Sleeper top
661	870	950	940 - 1 450	150 from end of sleeper	250 from end of sleeper	Wooden sleeper 865 concrete sleeper 665	785
457	400	1 000	1 420			500	
419	600	650				755	

removal of old track and laying of new track;

lifting and packing the raised track;

putting back the ballast;

complemental levelling carried out at a certain distance behind or a certain time after the first lifting and packing.

411. *What precautions do you take during these various operations to make sure of the perfect quality of the track i.e. resting on well compacted bed, settling in an uniform manner as the trains pass over, perfectly levelled and perfectly aligned? What machines do*

you use for the lifting, packing and complemental levelling?

The most important matter in the maintenance operations for high speed lines is to keep ballast correct. There are two generally known methods of laying ballast prior to the placing of track skeleton. One is grading the ballast under sleepers simply and putting the new track skeleton on it. The other is making the ballast under sleepers more compact by roller, vibrating machine, etc., while grading it completely by taking as basis the guide rails for the track skeleton carriers. In the former, work on the ballast under sleepers is simple, but thereafter it takes much time in lifting, packing and levelling, upon refilling the ballast between sleepers of the new track skeleton laid. When this methods is applied, it is often the case that the ballast is made compact by trains operated under speed restrictions for certain period between the first packing and levelling immediately after the initial lifting of track skeleton and the final packing and levelling.

When the latter method is applied, the ballast under sleepers is made compact by machines and the new skeleton takes naturally the right position, so the levelling after putting back the ballast is completely made by simple tamping. But, in this case, compacting of ballast prior to laying of track skeleton needs heavy equipment and takes much time, calling for a longer time interval between trains.

TABLE 411. — **Machines for levelling.**

Railway	*Kind of operations*	*Equipment*
Britain	Tamping Complemental levelling	Matisa, Plasser tamper Same tie-tamper and shovel packing
C & O	Lifting track Tamping	Power tamping jack; Nordberg track surfacer; Power track liner Jackson, McWilliams, Matisa, Plasser multi-tamper
Egypt.	Lifting track Tamping	Lifting jack Tamping machine
Finland	Lifting track Tamping	Plasser lifting machine; Jack Plasser, Matisa, Jackson Large-sized tamper
Ireland	Tamping	Matisa, Jackson tamper
Japan	Lifting track Tamping	Lifting jack; Kershaw Jack-All Matisa, Jackson and Japanese multi-tampers
Seaboard . . .	Lifting track Tamping	Tamping power jack; Track liner Tamping machine
Soviet Union .	Lifting track Tamping	Electric ballast operating machine; Electric sleeper lifting machine; Alignment correcting machine Travelling tamper
Sweden . . .	Lifting track Tamping Complemental levelling	« Robel 27 » jack « Matisa Standard » packing machine « Matisa BL » packing machine; « Vibro » « Cobra » Swedish packing machine

Kinds of equipment used in various countries for lifting, packing and complemental levelling are listed in Table 411.

412. 1. *What speed restrictions do you impose during the different phases of this work?*

Speed restrictions during the track renewal work vary with the methods of work and the interval during which the work is carried out. In case the work is for a time intermitted and old and new track skeletons are temporarily joined leaving a portion of track short of ballast so as to let trains pass the section, in the cause of a series of operations of track renewal covering a fairly long section of about 1-3 km from the site of ballast cleaning to the site of track skeleton renewal and final tamping, speed restrictions are imposed as follows:

a) 15-30 km/h, from the site of the ballast cleaning to the site of the first lifting and packing;

b) 50-80 km/h, from the site of lifting and packing to the site of complemental levelling;

c) over 80 km/h, after complemental levelling.

In cases where the track is renewed completely at one time over the whole section during the interval of trains, speed restrictions vary according to how far the levelling and aligning are completed. Where the track condition is good, train speed is limited to 50-80 km/h for the first train only. Where the track condition is not so good, speed restriction is imposed for several days and then the speed is gradually raised as the ballast becomes stable.

The speed restrictions practised in various countries are listed in Table 412.1.

TABLE 412.1 — **Speed restrictions.**

British Rys	When ballast has been disturbed	32 km/h
Egyptian Rys	1st day 2nd day 3rd day	8 km/h 30 km/h no restriction
Finnish Rys	During the lifting and straightening	15 km/h
Indian Rys	Within a week of renewal After two tamping operations Thence the speed is gradually raised.	16 km/h 32 km/h
Irish Rys	Through renewals	40 km/h
Japanese Rys	Firs. train Subsequent several trains After complemental levelling	25 km/h 60-80 km/h no restriction
Seaboard Rys	Through renewals End of day's work	48 km/h no restriction
Soviet Rys	First train Subsequent several trains After the track is stabilized completely	15 km/h 25-40 km/h no restriction
Swedish Rys	After track skeleton is laid After the first lifting and tamping After complemental levelling	20 km/h 60-70 km/h no restriction
T & P Rys	Through renewals	32 km/h

412.2. *Do you impose speed restrictions on the adjoining track when this is normally run over at high speeds?*

Generally, no speed restriction is imposed on the adjoining track. But when certain types of equipment are used, there may be cases where such speed restrictions are applied. In Soviet Rys, speed is limited to 50 km/h when track renewal work is carried out with a ballast cleaner and track skeleton depositer. T & P Rys limit the speeds to 72 km/h on the adjoining track.

413. *What tolerances are allowed when finishing the work (please join typical report) and if necessary what recordings are taken?*

Tolerances at the finishing of a track renewal work vary with the work methods, the time interval available for work, etc. Generally the tolerance are ± 1. ± 3 mm for gauge, cross level, longitudinal level and alignment; and ± 1 mm/m for distortion (Sweden, Japan, etc). The items to be recorded, besides the 5 items mentioned above, are superelevation, the profile of rail around the weld (India, Sweden, Japan, etc.).

414. *How soon after normal speed is allowed do you undertake the first levelling?*

Depending on the conditions of the section (particularly the train speeds and the gross tonnage of trains operated on the line), the work method used and other circumstances, the first levelling is generally undertaken 3 to 6 months after normal speed is allowed. But levelling may be required within a month if the ballast does not stabilize completely.

42. *Periodicity.*

421. *What is the periodicity of complete renewals of the permanent way as function of the importance of the line or of the tonnage carried?*

The periodicity of complete renewal is mostly 20 to 40 years, though it varies with the gross tonnage carried, and the characteristics of the track. Soviet Rys has reported that, the established rules provide that they must carry out complete renewals at 400 million gross tons in the case of a track laid with P-50 rails, with crushed stone ballast and sleepers spaced at 1 800 pieces per km.

In the case of the New Tokaido Line of Japanese Rys, the period is estimated at 10 years for complete renewals according to the calculation mentioned in Answer 336.

422. *Do you replace rails between two wholesale renewals of the tracks?*

Rails are rarely replaced between two wholesale renewals of track, because in figuring out the periodicity of complete track renewals the useful span of life of rails, as considered from the gross tonnage, train speeds, etc., is also taken into account. But when rails are exceptionally handicapped, as on sharp curves or on sections where they are extremely liable to wear and tear, they may be replaced earlier.

423. *Do you re-use old rails when replacing rails on lines run over at speeds 120 km or 75 m.p.h. or over? If so, what treatment have these undergone in the shops (perfect joints obtained by welding the rails and recutting in the solid bar, grinding, planing, reprofiling, straightening, etc.)?*

In replacing rails on lines where trains run at 120 km/h or over, most railway administrations use new rails. Used rails are rarely laid on such lines of great importance. On some railways (Soviet Union, T & P, etc.), however, used rails are welded to a specified length and re-laid, after cutting off the ends.

43. *Replacement of points and crossings*

Is this done without speed restrictions? If so, what precautions are taken?

Total replacement of points and crossings is generally done under speed restrictions. However, it may be carried out without speed restrictions, if sufficient time between trains is available for the work as well as for the tamping, and if the new points and crossings are all perfectly fabricated prior to installation. It is possible to carry out the work with good accuracy and, moreover, assign much time for tamping, by laying such a turnout equipment under the said conditions.

5. Maintenance methods.

51. *Periodicity.*

Is your maintenance work organised according to definite cycles? If so please give details.

Many countries have their maintenance work organized according to definite cycles on high-speed tracks, ranging from 1 to 7 years. In Swedish Rys, for instance, additional ballasting, spot resleepering, treatment of the joints and levelling and aligning, etc. are performed at a cycle of 6 years. In Indian Rys, general overhaul, including the cleaning of boxing ballast, is carried out at a cycle of 3 years. In T & P Rys, the maintenance work is performed on tracks carrying traffic of 15 000 000 gross tons or more a year at the average cycle of 5 years; while in Soviet Rys, every 200 000 000 gross tons. In Seaboard Rys, the most important work, timbering and surfacing, are performed at the cycle of 4 to 5 years. C & O Rys carries out all maintenance work, other than rail replacement, at the cycle of 3 to 7 years. On the New Tokaido Line of Japanese Rys, almost all sorts of maintenance work are to be carried out in series at the time of general overhaul with the cycle of 1.5 years.

52. *Method of carrying out the work according to its nature.*

We are concerned with the following operations :

greasing the fishplates, treating the joints;
pulling rails in order to restore correct joints;
tightening the fastenings;
re-adzing the sleepers;
consolidating the fastenings;
rectifying the gauge;
replacing sleepers;
replacing rails where necessary;
removing ballast.

521.1. *Under what conditions do you allow trains or Diesel-cars to run at full speed through section where work is in hand on the track in particular when work is being prepared and when traffic is restored after a work protected by hand operated stop signals? Please give the permitted proportion of sleepers without fastenings, ends of sleepers without fastenings on the same stretch of rails, etc...*

The permitted proportion of sleepers without fastenings for trains running at full speed is about 1/6 in Egyptian Rys. Continuation of more than two of these sleepers is avoided in Indian Rys, Finnish Rys, Egyptian Rys and Japanese Rys. Running at the maximum speed is to be allowed after the completion of such operations as fishplate greasing, joint treatment, pulling rails to restore correct joints, sleeper replacement, etc. The top speed is believed also permissible where only part of the ballast between the sleepers is yet to be restored, or where only one sleeper is not rendering adequate support to rails.

521.2. *When carrying out the above operations, how is the work divided up into different stages?*

Many countries are performing the above operations, excluding those for building up the joints and pulling rails in order to restore correct joints, as a series of work to be performed at the time of general overhaul; but in those countries where the cycles of these operations do not conform with each other, there are instances where these operations are no taken up at the same time.

522. *Please state how such operations may differ in the case of the same work carried out on lines run over at speeds below 120 km/h or 75 m.p.h.; please also indicate what you consider to be of importance as regards the quality of the track,* for example :

522.1. *Treatment of joints :*

Is the wear of the contact surfaces of the rails and that of the fishplates checked at each general overhaul? Is unsymmetrical wear on double track taken into account? (Append all useful data and drawings on methods used to make good wear : Shims hot pressed or welded up fishplates, etc...

At each general overhaul, the fishplates are removed for inspection at sight in many countries. With Japanese Rys, the joints are checked annually in connection with the inspection of rails for the breakage of ends. For the fishplate repairing, the hot press method is used in general as shown in Table 522.1. As for pressing, several press types are prepared in some instances to make the fishplates fit in the rails variously worn out.

522.2. *Tightening the fastenings.*

What rules are in force as regards the cycle of work in connection with tightening or checking the tightness of the fastenings, in accordance with their kind ?

As it has become comparatively easy to maintain the rail fastening force, where elastic fastening is used, many countries seem to have lengthened the cyclical period of repairing to once or twice every year. Among the countries which furnished the reports, Egyptian Rys calls for checking twice a year, at the beginning of spring and autumn, Seaboard Rys once annually during the summer and Irish Rys once every four years.

TABLE 522.1. — **Treatments of joints.**

Railways	*Checking*	*Periodicity*	*Joint repairing*	*Remark*
Egypt	At sight at the general overhaul		Shims	
India	At sight		Re-pressed fishplates	Shim is not suitable for high speed
Ireland			Re-pressed fishplates Shim	
Japan	At sight (Removing fishplates)	Annual	Re-pressed fishplates	
Sweden	At sight at the general overhaul		Re-pressed fishplates	Shims not used

522.3. *Rectifying the gauge.*

What variations in the gauge are found as time goes on, on straight sections and on curves, with wood and with concrete sleepers?

What is the maximum difference allowed in the gauge over a zone of a certain length, on track with base-plates and on track without?

What is the maximum permitted variation in the gauge from sleeper to sleeper?

According to the experiences of Japanese Rys, on the track (50 kg, 25 m rails, wooden sleepers with tie-plates) with a traffic of 30 000 000 gross tons a year, the average growth of track irregularity is about 0.001 mm per day on the straight track and about 0.001 mm per day on the curve (R = 400 to 500 m). The growth of track irregularity is less on the sections with tie-plates than those without.

The tolerances of gauge are in Soviet Rys + 6 mm and — 2 mm, T & P Rys + 5 mm and — 3 mm (wooden sleepers with tie-plates), Japanese Rys + 6 mm and — 3 mm (New Tokaido Line) and + 7 mm and — 4 mm (existing narrow-gauge lines), Swedish Rys + 6 mm and — 3 mm (R > 1 000 m), + 12 mm and — 3 mm (R < 1 000 m).

It seems from actual experiences that on the high speed tracks, the variation in the gauge is more important than the deviation from specified value of the gauge itself. The maximum permitted variation in gauge from sleeper to sleeper is 1 mm in Egyptian Rys and 1 to 2 mm in Indian Rys. The variation in gauge is 1 mm/1 m in Japanese New Tokaido Line and 1 mm/2 m in Soviet Rys.

522.4 *Replacing sleepers.*

What is the maximum percentage of sleepers per unit of rail length (1) *which can be replaced at one time without imposing speed restrictions (short rails, long rails)? What time must elapse between successive operations? What is the maximum permitted lift on the track? What change must be considered in the previous points in the case of very high speeds?*

What time must elapse before relevelling is carried out?

The maximum percentage of sleepers per unit of rail length that can be replaced at one time without imposing speed restrictions (short rails, long rails) : in the case of short rails, 3 sleepers in Egyptian Rys; and 10 % in Indian Rys, provided the sleepers are not consecutive. In Japanese Rys, replacement of consecutive sleepers is prohibited, and the work is so performed as not to worsen the vibration of rolling stock. In the case of sections with long rails, 5 sleepers can be replaced to each 50 m in Egyptian Rys. With Japanese Rys, it is performed, in principle, at the time of track renewal, and the sleepers are replaced one by one in other cases when necessary.

Time to elapse between successive operations : with Egyptian Rys, it is 2 hours, while with Japanese Rys only after the previously replaced sleepers have well settled on the ballast.

The maximum permitted lift of the track with Egyptian Rys, it is 50 mm, with Indian Rys 76 mm, Soviet Rys 20 mm, and Japanese Rys 30 mm.

The change to be considered in the previous points in the case of super-high speeds : in the case of super-high speeds, the number of sleepers to be renewed at the same time must be reduced, and the height of track lift must also be brought down according to most countries. When a train is to pass through at a super-high speed immediately after the work, it is also regarded as preferable in most countries to allow a sufficient time for carrying out the work under possession of track to be exact and precise.

Time to elapse before relevelling is carried out : it is 24 hours in Egyptian Rys, 1 week in Indian Rys and 1 to 2 days in Japanese Rys.

(1) Length of rails as are normally supplied by the rolling mills.

522.5 *Replacing individual rails.*

Are they replaced by rails with the same amount of wear obtained by reprofiling in the works, or cranked fishplates used to make the tops equal?

In Indian, Swedish, Soviet, Seaboard, Rock Island and C & O Rys, rails are replaced by those with the same amount of wear, grinding the surface when necessary; in Irish Rys cranked fishplates are used, and in Japanese and Egyptian Rys both methods are used.

522.6 *Removing ballast.*

What rules do you apply to the removal of ballast without imposing speed restrictions? What is the maximum depth of ballast that can be removed compared with the base level of the sleepers? Removal of the ballast from ends of sleepers: what is the maximum permitted number of consecutive sleepers from which the ballast can be removed and the maximum permitted percentage of sleepers from which the ballast can be removed per unit of rail length?

In Irish and Egyptian Rys, the maximum depth of ballast without imposing speed restrictions, is down to the base level of the sleepers, while in Indian and Japanese Rys, down to 50 mm from the sleeper base level between the sleepers.

As to the removal of ballast from sleeper ends, the maximum permitted number of consecutive sleepers and the maximum permitted percentage of sleepers are 3 sleepers and 25 % in Egyptian Rys. In Japanese Rys, it is removed from consecutive sleepers for up to 30 m in the case of short-rail sections, and hot days are avoided for this work.

53. *Levelling and aligning the track; shifting the tracks.*

531. *What are the tolerances applied when laying the track and what are they during maintenance before intervention (distortion, superelevation, surfacing, realigning) how are these influenced by the speed?*

The tolerance in various countries are as shown in the following table:

TABLE 531. — **Tolerances for track irregularities.**

Railways	*Speed*	*Tolerance for distortion*		*Tolerance for cross level*		*Tolerance for longitudinal level (10 m chord)*		*Tolerance for alignment (10 m chord)*	
		When laying	*During maintenance*	*When laying*	*During maintenance*	*When laying*	*During maintenance*	*When laying*	*During maintenance*
Japan *New Tokaido Line*	200 km/h	1.5 mm / 2.5 m	3 mm / 2.5 m	2 mm	5 mm	2 mm	5 mm	2 mm	4 mm
Narrow-gauge lines	110 km/h		4 mm / 2.3 m	Straight	6 mm		7 mm		5 mm
				Curve $R \leq 800$ m	7 mm		7 mm		7 mm
Sweden	105-130 km/h		4 mm / 2 m	3 mm	4 mm	2 mm	4 mm	3 mm	8 mm

The tolerance for the track irregularity is the most important factor in operating trains at a high speed; and to raise the speed, it is necessary to keep the track irregularity within a small tolerance at all times. It is considered that the growth of track irregularity quickens as the speed is raised, so one big factor in making high speed operation of trains possible depends on whether or not the track irregularity can be kept down within the tolerances. Although a smaller tolerance is good for passengers' riding comfort, such will increase the amount of maintenance work. So great care must be taken in determining the value of tolerance.

There are three kinds in tolerance of track irregularity : the tolerance applied on the track on the completion of track renewal, the tolerance to be observed on the completion of general overhaul and the tolerance to be kept at all times for maintenance. The first two kinds of tolerance are not determined only from the standpoint of safety or riding comfort of running trains. The third kind of tolerance is considered most important for high speed operation of trains.

As to the tolerance to be kept at all times for maintenance (tolerance before intervention) Japanese Rys plan for its New Tokaido Line as follows :

1) irregularity of track loaded with train or that of track not loaded : the track irregularity should essentially be measured only when the train load is working on the track. To measure it when the train load is not working is but an approximation. Since at high speeds, the tolerance will have to be reduced, it is necessary that the error of the measurement is small. It is for this reason that the method of measuring the irregularity of track loaded with train is preferable;

2) how the tolerance figures are to be interpreted : from the experiences of Japanese Rys, it was found difficult to maintain the track by strictly observing the tolerance to be kept at all times when it represents the tolerance with the train load taken into consideration. However generally speaking, this tolerance is for the tolerance designed to secure riding comfort; and as there is a considerable allowance made in it against derailment, it does not necessarily mean that when the tolerance is exceeded the train will have to be slowed down at once. The tolerance means that when it is exceeded the field operators must be contacted immediately for repairing as soon possible. That goes to show, strictly speaking, that there are instances where the tolerance is exceeded by several percent immediately before the track irregularity is measured;

3) items measured : from the result of high-speed test runs, it can be said that the deviation from the specified value alone of gauge, cross level, etc. does not greatly affect riding comfort and that the vibration of rolling stock is largely affected by the distortion, the variation in gauge per meter, the variation in alignment per meter and so forth. Accordingly, the amount of variations has been mainly taken in considering the items. For this reason, the track inspection car for the New Tokaido Line is to be so equipped as to record the gauge, cross level, alignment and longitudinal level as well as their second-by-second differential values, and others;

4) chord length used in measuring alignment and longitudinal level : according to the actual figures for rolling stock vibration obtained so far, the following tendency is noticeable; the hazard is greatest when there are irregularities on the track and when their cycle corresponds to that of the hunting motion of rolling stock. The cycle of irregularities on the track that does not correspond to the cycle of hunting motion sometimes acts in such a way as to reduce the vibration of rolling stock. It seems, therefore, desirable to set the chord length at 1/2 of the wave length of rolling stock's hunting motion. However, because actually the chord length of 10 m has been in use heretofore and also because it has been found more convenient in manufacturing high-speed track inspection cars, we have

decided to continue using it for the time being;

5) distortion (Variation in cross level) : in measuring the distortion by the track inspection car, we have seen to it that the basic length would be same as the wheel base of the New Tokaido Line's rolling stock (2.5 m) and that the inspection car would have a bogie structure as similar as possible to that of the passenger electric railcar and that its profile of tyre would fit in to that of the railcar. Furthermore, as the turnouts of the New Tokaido Line will have neither a gap between the nose and the wing rail nor the guard rail, it is not necessary to have guide plates equipped on the inspection car to have the small measuring wheels pass over the gap.

With all these considerations taken into account, the tolerances are determined. A series of test is scheduled to be conducted after June, 1962, in the sections to be completed by then in order to set the tolerances for final use.

532. *Levelling.*

532.11. *What is the maximum height of lifting?*

The maximum heigth of lifting for each operation depends upon the capacity of the lifting and tamping machines and tools. However, for safe operation, the height of lifting should not be so big as not to allow completing the tamping before the train runs through. So it might be said that the height of lifting depends on the time available for work and the speed of the train passing through, as well as on the capacity of the machines to be used.

The maximum height of lifting in various countries is more than 50 mm for operation performed under possession of the track in Japanese Rys, 50 mm in Egyptian and Seaboard Rys, 76 mm in Indian Rys, 100 mm in Finnish, T & P, C & O and Irish Rys, and 180 mm in Soviet Rys.

532.12. *How are the run-outs being maintained during the work and at the end of the day's work?*

The grade of run-outs during the work is 1/240 in British Rys, and 25 mm/rail length (11 to 13 m) in Indian Rys. At the end of the day's work, it is 1/720 in British Rys and 13 mm/rail length in Indian Rys. Among the railway systems using the same grade both during the work and at the end of the day's work, Egyptian Rys have it 1/500, Swedish Rys 1/150 and Japanese Rys 1/500.

532.13. *Are you considering to make any modifications to these rules in the case of very high speeds?*

When the speed exceeds 150 km/h, it seems necessary to properly reduce the grade of run-outs and to do the tamping thoroughly. Again, when the time for work is short, it may become necessary to reduce the height of lifting for each operation. As Japanese Rys has 3 or 8 hours available for work each day on the New Tokaido Line, Japanese Rys plans to use a grade less than 1/1 000 for run-outs and to do the tamping thoroughly.

532.2 *Do you take special precautions as regards lifting before passing of fast railcars?*

Although no special precautions are taken in Egyptian, British, Indian and Seaboard Rys, they stop lifting, pack the track well and make a ramp. As Japanese Rys have a very short time available for the work on their narrow-gauge lines, no lifting operation is, in principle, performed before passing of fast railcars.

532.31. *What conditions must be observed to obtain thorough levelling and by what method is this obtained?*

Thorough levelling demands exact lifting of rail according to the standard pegs prior to tamping, and is largely dependent on the capacity of the tamping machine, frequency of the tamping, skill of the operators, the precision of the measuring instrument and so forth. Many countries say that the best

result can be had with a multiple tie-tamper. When considered from the standpoint of exactness of tamping, the space of lifting carried out prior to the tamping is important and the desirable space between points to be lifted prior to tamping on high-speed tracks, is 3 to 5 sleepers. It seems that better results can be attained in respect to exactness and efficiency by using a superior heavy machine for the lifting prior to tamping. In the case of shovel packing, small crushed ballast is laid to the width of about 400 mm to each side of rail.

532.33. *How do you propose to carry out maintenance levelling in the case of very high speeds?*

In order to reduce the variation of deviations per meter of the track, as measured when the train load is working on the track, as well as to enhance the exactness of work on super-high speed tracks, the tamping is desired to be carried on so as to have even compacity, and the automatic large machine seems to be preferable for lifting and tamping purpose.

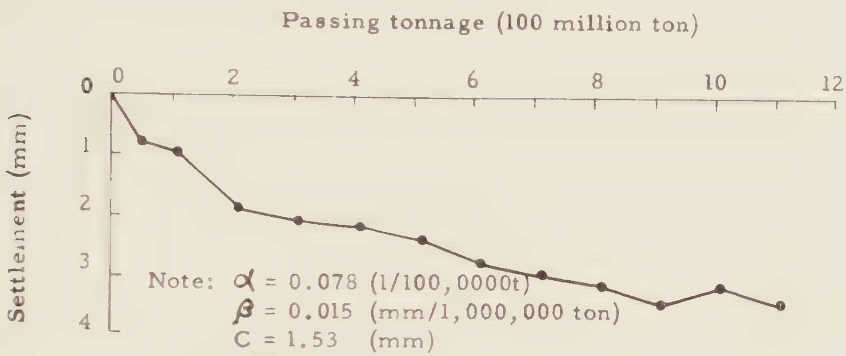


Fig. 532.41. — Settlement curve of Japanese Rys.

532.32. *What is the effective duration of packing and thorough levelling as a function of the number of trains and railcars?*

The effective duration largely varies according to the nature of the roadbed, drainage, track structure, passing tonnage and tamping skill. In Egyptian Rys, it is every 12 000 passes of trains in the crushed ballast sections and every 3 000 passes of trains in the round ballast sections, 4 years in Seaboard Rys, every 60 to 90 millions gross tons in T & P Rys, 1 to 1 1/2 months in the crushed ballast sections of Soviet Rys. With Japanese Rys, continuous thorough tamping is performed once a year to recover the compacity of ballast, and the partial levelling is performed at an average rate of every rate of every 27 000 passes of trains (6 months).

532.41. *What results have you obtained from trials as regards the importance of loss of compacity after levelling and its evolution as time goes on?*

The degree of track settlement after levelling depends on the roadbed quality, track structure, tamping method and passing tonnage. The settlement curve obtained from the experiences and used by Japanese Rys is as follows:

$$Y = Ce^{-\alpha x} - \beta x - C$$

where Y is settlement of rail level, x ; total gross tonnage after tamping, α, β and C; cœfficients. « β » in the given cœfficients is determined by the track structure and roadbed; while « C » and « α » are considered to be mainly relative to the tamping result. For illustration see figure 532.41.

This illustration shows that the rail level rapidly sinks down during a short time right after the tamping, then the sinking slowly continues, finally almost in a straight line.

532.42. *How long does take a track to become stable?*

The time required for the track to become stable depends on various factors. However, it can generally be said that the rapid sinking of the track ceases after passes of 1 to 5 trains (Seaboard and Egypt). Many countries are of the opinion that it takes around 30 days for the sinking to become very slow.

Straight sections are aligned from one stretch of rails.

533.21. *Are curves and their transitions pegged out? What is the distance between pegs? Is the pegging checked periodically?*

Most countries peg out curves and their transitions. The distance between the pegs is 60.6 m in Indian Rys, 6.86 m in Irish Rys, 20 m in Finnish and Egyptian Rys, 15.3 m in T & P Rys, 10 m in Japanese Rys, and 15.3 m or less in Rock Island Rys. The pegging in many countries is checked

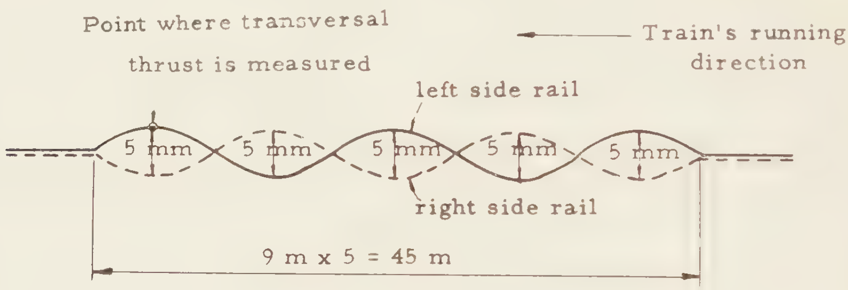


Fig. 533.32. — Track condition.

532.51. *How do you measure defects in the level of joints?*

A ruler, 1.2 to 2 m in length, is commonly used, by placing it on the rail to measure the defects in the level of joints.

532.52. *How often are joints levelled according to the importance of the line?*

It depends on the structure of joints, the passing tonnage, etc. The levelling is performed at the periodicity of 2 to 12 months as necessity arises.

533. *Aligning.*

533.1. *How do you align straight sections, on the centre line or from one stretch of rails?*

about once a year in addition to the checking at general overhaul.

533.22. *At which points are the ordinates checked over the length of cord corresponding to the pegs?*

The ordinates are generally checked in most countries at the center point over the length of cord corresponding to the pegs.

533.31. *Is aligning carried out immediately after levelling?*

In every country, aligning is carried out, in principle, immediately after levelling.

533.32. *What is your opinion about the lasting value of aligning carried out independently of levelling?*

Most railway systems are opposed to aligning being carried out independently of levelling. Japanese Rys once experimented on this subject. With the distortion illustrated in figure 533.32 on the track after thorough aligning, railcars were run at the speed of 95 km/h to measure the transversal thrust at the rail and at the wheel. The transversal thrust thus measured was 4.2 tons. Should such thrust continue acting, some irregularities in alignment are expected to occur.

533.4. *How often does aligning take place according to the importance of the line, with short rails and with long rails?*

The periodicity of aligning varies depending on passing tonnage, track strength, tolerances and so on. In the short-rail sections, aligning takes place at the maintenance periodicity of 2 to 12 months. In the long-rail sections, it is necessary to make the tolerances small, in order to prevent buckling. This means a short cyclical period of maintenance. Actually, however, with the structure of track so made as to have a greater resistance against the transversal thrust and also there being no joints, the growth of irregularity in alignment is slow; and the cyclical periodicity of aligning is lengthened to about once every year (Japan and Soviet Union).

534. *Shifting.*

What is the maximum shift at a time, with short rails and long rails?

In deciding on the maximum shift, the interval available for work is considered, paying attention at the same time to the

TABLE 535.11 — **Means to record the track condition.**

Railways	*Means*
Britain	Matisa track recording trolley
C & O	High speed inspection car
Egypt	Hallade track recorder Matisa trolley recorder
Finland	Matisa dynamometer car
India	Hallade track recorder Track recording car
Ireland	Hallade track recorder
Japan *New Tokaido Line* . . *(Standard gauge)*	High-speed track inspection car (dead weight, 68 tons)
Narrow gauge lines .	High-speed track inspection car (dead weight, 46.5 tons) Medium size track recording trolley Small size track recording trolley
Soviet Union	Track recording car Track recording trolley operated by hand
Sweden	Mauzin track recording coach Small Matisa recording car

axle force in particular, in the case of long rails, and to the joint clearance in the case of short rails. With short rails, the maximum shift is larger than that with long rails. And many countries think that a considerable shifting is possible if properly and adequately worked out. With long rails, excessive shift is avoided; and when necessary, it is carried out at a temperature between ± 10°C — ± 15°C of the laying temperature.

535. *Operations of levelling and aligning.*

535.11. *What means do you use to record the condition of the track (coaches, light engines on rails)?*

The replies to this question from various countries are given in Table 535.11.

Thus, in most countries large coach type track recording cars or small trolley type track recorders are in use. The high-speed track inspection car, both for narrow and standard gauges, of Japanese Rys mechanically measures the irregularities of track and record them electrically. In addition to the device to record the track irregularities, an automatic computing device is used to type and print out the number of points where track irregularities exceed the tolerance.

535.12. *How often are such checks carried out?*

The period of inspection in various countries are ar shown in Table 535.12.

535.13. *Have you tried any system of figures to judge of the condition of the track?*

In Swedish Rys, the condition of the gauge, distortion, cross level and alignment is shown in 5 stages, ranging from 0 to 5, using the data obtained by the use of the Mauzin track rocording coach. In Soviet Rys, the track conditions of the crushed or round ballast sections using rail of P-50

TABLE 535.12. — **Period of inspection.**

Railways	*Period of inspection*
Britain	Not definitely set.
C & O	Twice a year by track recording car.
Egypt	Every three months.
Finland	Once a year by track recording car.
India	Twice a year.
Ireland	Once a year at least.
Japan	Once a month at least by high-speed track inspection car on the New Tokaido Line. On the narrow-gauge lines, four times a year by a high-speed track inspection car.
Soviet Union	Once or twice every three months by a track recording car. More than once a month by hand-operated track recording trolley.
Sweden	Twice a year by Mauzin track recording coach on high-speed tracks. Every second months by small Matisa track recording car.

or over are shown in the number of marks and are divided into 4 stages.

In Japanese Rys, the following method is used.

1) The irregularities of the track : The index of track irregularity P is used in judging the track condition. P denotes the percentage of the aggregate length of tracks with irregularities exceeding $\pm$ 3 mm. Formerly, assuming tha the numerical values of track irregularities distribute normally, P was calculated by a mathematical method. Lately, the P is calculated section by section with an automatic computing device equipped on the high-speed track inspection car.

2) Vibration acceleration of rolling stock: The vertical and transversal vibration acceleration is measured by the high speed inspection car and is classified by the standards given in the following table :

TABLE 535.13. — **Judgement by vibration acceleration.**

Less than 0.1 g	*0.1 - 0.2 g*	*Over 0.2 g*
Good	Require care. (Investigate the cause and rectify the points where such is necessary.)	Unsatisfactory (Rectify at once.)

3) Unsatisfactory condition of track components : The unsatisfactory conditions of various track components are shown items by items in percent.

4) Growth of track irregularity : The growth of track irregularity S is used as the index for track strength, and the priority in improvement of the track is given to where the S is great.

$$S = \frac{b - a}{n},$$

where a is the irregularity in mm at a certain point, b, the irregularity in mm when neglected for n days at that point, and S, growth of track irregularity in mm/day. Actually, this value of S is read from a self-recording device installed on the track.

535.2. *What is the average quality obtained according to the age of the track and the importance of the line, with short rails and with long rails? Please join samples of the recording strips*

Normally, good running is obtained on rails of the age up to about 25 to 35 years and on sleepers with percentage of unserviceability below 20 with short rails in Indian Rys. In Soviet Rys, the track condition of 5 to 6 marks is usually maintained on high speed tracks. (There are 4 grades set, and the excellent grade being 0 to 15 marks.) The track condition of high speed narrow gauge lines of Japanese Rys shown by P (see answer 535.13) is in the following table :

TABLE 535.2-1 — **The track condition P.**

P	*Gauge*	*Cross level*	*Longitudinal level*	*Alignment*	*Distortion*
Irreguralities of track loaded with train	12	10	27	19	6
Irregularities of track not loaded . .	8	8	18	11	—

The track condition for long and short rails according to the age of such rails is shown by P in the following table :

TABLE 535.2-2 — **The track condition P (Irregularities of track loaded with train).**

Kind of length	*Age*	*Gauge*	*Cross level*	*Longitudinal level*	*Alignment*	*Distortion*
Long rail	1 yr. 5 yrs.	0 3	1 3	16 18	10 13	0 4
Short rail	5 yrs. 15 yrs.	5 12	5 9	23 37	18 24	5 9

535.3. *What is the annual percentage of continuous track levelled and aligned (the levelling of the joints being turned into an equivalent length of continuous levelling as a function of the time taken) and the percentage of track aligned only, according to the speed and the importance of the line, with short rails and with long rails.*

Levelling and aligning are carried out, in principle, at the same time, but the percentage of the track aligned only is reported to be about 30 % (Egypt, Japan, etc.). As to the effect of speeds on levelling and aligning, Soviet Rys replied that they do not increase the levelling for a higher speed but they do aligning oftener. Most countries reported that there is hardly any difference between long and short rails sections.

535.4. *Are you considering any modification of these data for very high speeds, as this would modify the importance of defects in the track?*

At super-high speeds, the growth of track irregularity seems to quicken and it seems necessary to reduce the tolerance of track irregularity. To do so, it is deemed necessary to increase the frequency of measuring by the inspection car, and further to secure the exactness of the measuring device, placing emphasis on the measuring of the variation of irregularities, such as distortion, variation of the gauge, variation of alignment, etc.

54. *Other operations intended to improve the quality of the track.*

541. *Building up the joints.*

541.1. *What is the minimum wear of the ends of the rails which — justifies building them up?*

The minimum wear reported by C & O, Seaboard, Rock Island and T & P Rys is 0.8-0.9 mm, Egyptian, Finnish, Swedish and Japanese Rys 2 mm, and Soviet Rys 3 mm. Irish and British Rys have no specific provisions made.

541.2. *What is the maximum thickness and length of the built up metals?*

The maximum thickness and length of the built-up metals in various countries are as follows :

Egyptian Rys . .	5 mm	200 mm
Swedish Rys . . .	5 mm	300 mm
Japanese Rys . .	5 mm	500 mm
Seaboard Rys . .	6.3 mm	305 mm
Finnish Rys . . .	6.3 mm	1,000 mm
Soviet Rys . . .	—	200 to 300 mm

541.3. *How long is the period between two successive reconditionings on main lines?*

It varies depending on the passing tonnage, weight of axle, speed and track condition. It is 5 to 10 years in most countries.

541.4. *Please append information about the way work is done.*

Egyptian Rys reconditions by arc welding, and so does Swedish Rys today, though the latter used to do it by gas welding. Japanese Rys also uses arc welding. Rock Island Rys does gas welding. The details are as follows:

In Swedish Rys, if the rail ends are not only worn but also deformed by crushing, the head of the rail is heated to 800°C and reformed by hammering. After that the missing metal is built up by gas welding. Normally longitudinal runs are laid but in case of much wear the first run at the very end of the rail is laid right across and the following runs are laid longitudinally. At last the rail ends are brushed and hammered in order to get a smooth running surface. The built-up metal has a Brinell hardness of 350° HB which is above the normal hardness of 220° HB for normal rail steel. During the recent years they have also practiced arc welding. After preheating to 400°C the new metal is built up by using coated electrodes ⌀ 3.25 mm of a Brinell hardness of 300° HB. The runs are longitudinal starting from the very end of the rail. After welding the rails ends are hammered. No post-heating is carried out.

In Indian Rys, the joint intended to be built up is well packed and the loose bolts, if any, are tightened. The top table of rails is cleaned for oil or any greasy matter. It is then heated with a neutral flame and cleaned off with wire-brush. Burrings, if any, on the sides of the railhead are removed with a set of cold chisels. The rail ends are again subjected to heat and as soon as the sweating starts, a deposition of metal along with a little excess acetylene is done. The deposited metal is forged on with 57 mm (2 1/4") long excess acetylene flame and a hammer (1 1/2 lbs. and 2 lbs. in weight). The rail end is then smoothened with a light taping hammer and a shaper.

In Japanese Rys, arc welding is done more or less in the same way as in Swedish Rys. Prior to welding, the rail end is heated at about 300°C. The electrode of low hydrogen type (⌀ 5 mm mostly), the built-up metal of which is of a Brinell hardness of 250° to 300° HB, is used. No hammer but the grinder is used for finishing.

542. *Grinding corrugated rails.*

Do you do this? If so, by what means, and what results have been obtained (short and long waves)?

In British and Swedish Rys, undulatory wear was hardly found, and grinding has never been done. In Irish Rys, small grinding machines such as Robel, Elektro Thermit, etc. are used for satisfactory results. C & O Railways does not usually, but when necessary, uses a large power machine, with several hundred grinding wheels working simultaneously. Seaboard Rys and T & P Rys use a work train specially equipped for grinding. In Soviet Rys, special wagons are used for grinding. Japanese Rys uses grinding machines in the field and planing machines in the track-material repair shops.

543. *Removing longitudinal burrs.*

Do you do this? If so, by what means and with what success?

In British, Egyptian, Swedish, Seaboard Rys and so on, no longitudinal burrs have been noted to obstruct high speed operation of trains. Some countries remove the longitudinal burrs of the points and crossings by cutter in their attempts to properly maintain the back gauge.

544. *Do you carry out any other operations intended to improve the quality of a track for very high speeds, or do you*

consider that very high speeds depend upon the carrying out of other operations than those mentioned above?

The best way to improve the joints is to use long welded rails, doing away with the joints.

In the case of very high speeds, it is desirable to keep down the growth of track irregularities as small as possible. As the growth of track irregularities largely depends on the loosening and sinking of the ballast, it seems to be advantageous to replace the ballast with a solid bed of concrete or with asphalt treated ballast, under good subgrade conditions, though they are not extensively used so far.

As to other considerations, many countries consider that the designing of roadbed is important in the case of super-high speeds in containing the growth of the track irregularities. Japanese Rys also sees to it that sandy soil of as small as possible liquid limit be used on the surface layer of the roadbed and that CBR be larger than 10 beneath ballast and K_{75} be larger than 3 (kg/cm3) 3 m under the formation level.

55. *Protection of manual and mechanized working sites.*

551. *Protection at sight.*

551.1. *The time the trains are visible should be equal to the time taken for clearing the line increased with a certain safety margin; what values do you allow for these times?*

In such operations as tightening the fastenings where the track can be temporarily restored and cleared in short time after interruption of work to have trains pass at high speeds, the system of protection at sight can be used. However, in the case of operations requiring comparatively much time for temporarily restoring and clearing the track, the system of protection by hand-operated stop signal is desirable.

In Swedish Rys and Japanese Rys, the safety margin is about 10 seconds. Time of visibility is the sum total of the time for restoring and clearing the track and the safety margin.

551.2. *Do you set a limit to the number of light machines (which can be taken off the rails by two men) used on the working site?*

In Egyptian Rys, the number is limited to less than 4, whereas in other countries no such limit is provided.

551.3. *In the case of a working site protected at sight, what does a train risk coming across in exceptional cases if the men are taken by surprise (joint on one stretch of rails without fishplates, missing sleeper, etc.)?*

When there is a single sleeper missing, or when 1 or 2 sleepers are without rail fastening, most countries think there is no special risk involved, as long as the track irregularities are kept down in the case of straight track. But when the rail joint is without fishplates, this particular point sinks down, giving rise to track irregularities as the train passes over it. This often affects the safety of passing trains: and the train will have to risk the possibility of derailment on curves, in particular.

552. *Protection by hand operated stop signal at a distance according to regulations.*

552.1. *What is the distance of protection in connection with permitted speed?*

Although the distance of protection has to be longer than the brake distance of the train, which varies in the case where there is a grade, it is generally fixed with a certain safety margin.

The distance of protection is 700 m in Finnish Rys, 800 m in Egyptian Rys and Japanese narrow gauge lines, 850 m in Indian Rys, 900 m in Swedish Rys, 1 200 m in Irish, Rock Island and Soviet Rys, and 1 600 m or more in Seaboard Rys.

552.2. *Do you make use of radio transmission? If so, under what conditions are there restrictions on its use, due for example to the configuration of the site?*

Radios are being used in C & O, T & P, Rock Island, Finnish and Japanese Rys. In Seaboard Rys, the gang and the train are equipped with them, and their radios are good for several miles distance. Those used in Japanese Rys are portable, about 4 kg in weight, 155 MC in VHF, 0.5 W in output, and transmit up to the distance of 4 km on level land.

552.3. *What system of protection do you use on the different working sites for the maintenance operation mentioned under point 52, and when levelling is being carried out, according to the characteristics of the site and other circumstances?*

The operations such as greasing the fishplates, treating the joints, pulling rails in order to restore correct joints, re-adzing the sleepers, replacing sleepers, replacing rails, etc. are desired to be performed under possession of the line between two stations. Most countries deem it necessary to carry out these operations under protection at least by hand-operated stop signal. Protection at sight by look-outs seems to be good enough for such operations as spot levelling with small height of lifting, tightening the fastenings, aligning with small shift, etc.

552.4. *What are the numbers of men employed on the mechanized maintenance working sites, taking into account the system of protection, number of trains, etc.?*

The number of men for maintenance work are:

At the working site for track renewal . . . . 50-100 men
At the working site for general overhaul . . . . 20- 60 men
At the working site for levelling and packing by multiple-tie tamper . . . . 10- 14 men

553. *Running of trains over adjoining track.*

553.1. *What steps have the men to take at this moment to protect their machines and themselves, according to the system of protection in force on the working site in question?*

Where there is no risk of obstructing the adjoining track during the operations, the look-out calls attention by horn; but when the operations, using large machines, are likely to affect the adjoining track, work is suspended by the horn signal from the look-out. The operation of a machine which raises so much noise as to distract the attention to the train on the adjoining track must also be stopped.

553.2. *Do you impose speed restrictions on trains running on the adjoining line when this is normally operated at high speed?*

Generally no restrictions are imposed. But when special work is to be carried out, some railways restrict the speed of the trains running on the adjoining line. (Soviet Union, T & P, Rock Island and Finland) (see Answer 412.2).

554. *Future speed of more than 150 km/h or 93 m.p.h.*

554.1. *Where are the men to go? Must they keep the paths clear? Case of narrow cuttings, viaducts, tunnels.*

According to Japanese Rys' experiments, even at the speed of 200 km/h, it is considered safe for men at the distance of 800 mm from the side of a stream-lined train where the train wind velocity is about 17 m/sec. Hence the men on the New Tokaido Line will be safe on the path, for the path here is to be set over 800 mm away from the side of rolling stock. The men are also safe on

the path even in the cutting and bridge section from the same reason. The refuge and path are to be set up as follows in the tunnels to save the construction cost :

554.23. *Substituting protection by hand operated stop signals for protection at sight on certain working sites (on curves and in cutting).*

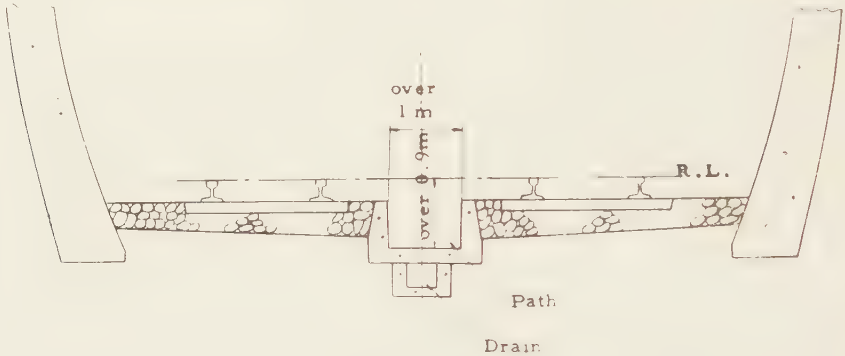


Fig. 554.1. — The path in the tunnels of Japanese New Tokaido Line.

554.2. *Have you considered increasing their protection by...*

554.21. *Increasing the time of visibility or safety.*

At a speed over 150 km/h, the train approaches at a speed of 40 to 50 m a second, and the distance of 500 m is covered by the train in 10 seconds. So, the safety margin has to be big enough, considering the danger involved. Moreover, the time for temporary restoration of the track has to be increased to have a train pass at super-high speeds. Accordingly, it seems necessary to increase considerably the time of visibility.

554.22. *Increasing the number of lookouts.*

To clear the line safely, a lookout has to be posted at a distance of about 1 000 m away from the working spot to ascertain the train approach, assuming 10 seconds for the safety margin, and another 10 seconds for the time in restoring and clearing the track. So it seems necessary to post other lookouts at interval within that distance of about 1 000 m.

In the sections where visibility is poor, such as in cutting and on curves, it is safe to resort to the system of the protecting by hand-operated stop signals. At super-high speeds, in such operations where the time for temporary restoration and clearing of the track requires, for example, more than 20 seconds after interruption of work for a train to pass at 150 km/h or more, the train approach will have to be ascertained at a spot at least about 1.2 km away from the working site, considering 10 seconds for the safety margin; hence it is desirable for the sake of safety to resort to the system of protection by hand-operated stop signals. Thus, it is considered that when trains operate at a speed over 150 km/h a considerably large number of operations call for the system of protection by hand-operated stop signal. Also, as the brake distance reaches about 3 km at the speed of 200 km/h, the means for stopping the train seem to be no simple matter at all.

554.24. *Other methods?*

The brake distance at the speed of 150 to 200 km/h will be 2 to 3 km, making

it difficult to arrange for the train stop in case of such need; however, on the track using the automatic signal and the track circuit, it is thought possible to do so by short-circuiting. That is to say, if the signal is of 4 indications, placed at an interval of 1 km, the signal will be indicated up to the spot about 4 km away from the working site, provided the short-circuiting is ensured, and this enables necessary preparations for the train stop.

554.31. *What is the extent of the additional time lost when increasing from 100/120 to 130/140 km/h (62/73 to 79/87 m.p.h.)?*

At high speeds, the work amount to restore the track to enable a train to pass the working site without slowing down its speed after interrupting of the work at the train approach, would increase and this means lowering the efficiency of work. Again, at high speeds, the time for refuge including a longer safety margin has to be increased. This means a loss estimated to reach about 20 %, though the percentage may differ dependent on the nature of work being carried out and on the number of passing trains.

554.32. *Please estimate the additional time lost in the case of speeds of more than 140 km/h or 87 m.p.h.*

Although it is thinkable that more time would be lost if the speed is raised over 140 km/h, it seems possible to avoid the loss of time by intensifying and mechanizing all operations. On Japanese Rys' New Tokaido Line, all the operations where the temporary track restoration requiring more than 20 seconds after the interruption of the work for the passing of the train at 200 km/h, are to be carried out intensively at night for 3 hours every day.

554.41. *In order to assure the safety of employees using the paths, what should be the distance from the edge of the path to the nearest rails?*

At the result of various experiments conducted for Japanese Rys' New Tokaido Line mentioned in Answer 554.1, the distance from the side of rolling stock to the edge of the path was determined for safety at 800 mm (from the nearest rail to the edge of the path, 1 750 mm) for the stream-lined 200 km/h trains.

554.42. *If it is no longer possible to use bicycles or powered cycles on the paths, what effects will this have on the organization of the gangs?*

If automobiles or powered cycles are not used on the path, the sphere of gangs' work would become less, necessitating the organisation to split further into smaller units for maintenance. This possibly means a lowering of working efficiency.

56. *Supervision of high speed lines.*

561. *Supervision of the track and its surroundings.*

561.1. *Is the distribution of the maintenance men over high speed lines in any way different compared with that on lines with similar traffic but with speeds of less than 120 km/h or 75 m.p.h.?*

On high-speed track, the track deterioration becomes faster and the tolerance of track irregularity is smaller, but, on the other hand, there are many cases where excellent materials are used for track structure and efficiency of work is raised. So, many countries replied, there is no need for a change in the distribution of maintenance crew.

561.2. *In the case where the gang is grouped and transported by lorry or truck, how is inspection carried out in the case of serious bad weather?*

In the case of serious bad weather, as many men as possible are put on guard. In those places where danger is expected beforehand, men are especially posted to pa-

trol on foot, while in other places bicycles and lorries are used in many countries to make inspection tour at a certain interval.

561.3. *Are additional inspections carried out in the case of lines with speeds of 120 km/h or 75 m.p.h. or over? In what cases?*

As the speed is raised, even a small track irregularity would greatly affect the train. So there are some railways, like Egyptian, Japanese Rys, etc. that intensify inspection. But there are others (Sweden, Finland, etc.) that do not always intensify inspection when the speed is raised, taking the track strength and the passing tonnage into consideration.

561.4. *In the future, in case of speeds of over 150 km/h or 93 m.p.h. how will the inspection tours be carried out on single and double tracks?*

Some railways replied that the inspection tours as carried out today will be sufficient if the track is adequately consolidated and efficiently maintained. For Japanese Rys' New Tokaido Line, the following points are considered :

1) since the effect of track irregularities on high-speed trains will be great, Japanese Rys plans to run a high-speed inspection car (see Answer 535.11) once a month at least. If necessary, this car can be coupled to the rear of a freight train, running at the speed of 130 km/h, for daily inspection of the whole line of 500 km, one way;

2) inspection personnel will be posted at the rate of 0.22 men per km for patrolling on foot and for data to be used in planning maintenance work.

562. *Prevention of deformation to the track.*

Above what temperature do you forbid any work in connection with lifting or entailing deconsolidation of the track? Please deal separately with the case of short rails and long rails.

Although no restriction is made on the temperature in the case of short rails, such work is avoided as much as possible in British, Japanese, C & O, T & P, Soviet Rys, etc. when it is extremely hot, especially paying attention to the condition of the joints. The temperature is set at 45° C in Egyptian Rys, 49° C in Indian Rys and 30° C in Swedish Rys.

In the case of long rails, it is set at 32 ° C in T & P Rys, 40° C in Egyptian Rys, and 30° C in Swedish Rys. Such work in forbidden when the temperature is lower or higher than the laying temperature by 11° C in British Rys and when higher by 15° C in Soviet and Japanese Rys.

563. *Inspection of rails from the point of view of cracks.*

563.1. *At what age of the rails or after they have carried what tonnage is the first sounding by a control apparatus (short rails, long rails) carried out, and how often after this are such sounding made?*

The first sounding of rail is made about 5 years after the rail is laid, using the supersonic or induction method, and once a year thereafter in many countries.

563.2. *Do you consider that very high speeds favour the development of defects in the rails?*

Generally speaking, it is deemed that the impact on the rail becomes greater as the speed is raised. It, is, therefore, considered in many countries that high speeds favour the development of defects etc. in the rails.

57. *Points and crossings.*

571. *What is the periodicity of checking the safety dimensions (protection of the point, guiding of the axles)?*

It varies to a certain extent depending on how important the turnouts are, and many countries have it set at about 1 to 3 months.

572. *What is the normal cycle of overhauls?*

It is generally 1 to 4 years, though it considerab.y differs depending on the passing tonnage over the turnout.

573. *What is the periodicity of levelling and aligning?*

In many countries, the levelling and aligning are carried out at the time of general overhaul and 1 to 3 times between the general overhauls, and it is about 2 to 12 months.

574. *Do you consider that any evolution will take place in the above methods in relation with very high speeds?*

Although super-high speeds will quicken the detoriation of materials and the growth of the track irregularities, it is thought there is no need to shorten the periodicity if the structure of turnouts is improved and consolidated as in the case of turnouts with movable nose crossing.

58. *Effects of high speeds on the maintenance of the permanent way.*

It appears likely that the practice of high speeds will involve the replacement of rails in a continuous series owing to the chamfering of the outer stretch of rails on curves, an increase in the number of times levelling and aligning of the running line and of points and crossings have to take place, increasing the protection measures of working sites, additional lost time due to the passing of trains, etc. As a result, do you increase the basic number of maintenance men per km or per mile in relation with the maximum speed?

In Swedish Rys, an increase in the basic number of maintenance men is thought not necessary, if the program of improving the track structure is carried on along with mechanization of operations in speeding up of their trains.

As for the New Tokaido Line, the basic idea of Japanese Rys is as follows: The deterioration rate of the New Tokaido Line track for 200 km/h trains is estimated to be faster by 1.2 fold over that of the existing lines track for about 100 km/h trains as mentioned in Answer 336. Assuming that the necessity of strictly observing the track maintenance tolerance due to the high speed will increase the work amount on the New Tokaido Line about 1.5 fold, the maintenance work is expected to increase 1.8 fold ($1.5 \times 1.2 = 1.8$) as compared with the existing lines. But there, under the maintenance system contemplated for the New Tokaido Line, will be available 3 hours daily at night except Sunday and 8 hours on Sunday night when the freight trains are to be suspended of operations. When we think of these long hours available for continuous operations and all the mechanization of operations that is possible with these long hours, we can safely assume the working efficiency can be raised by 45 %. That means, $1.8 \times (1\text{-}0.45) \doteqdot 1$. Thus, the work amount remaining practically about the same, it is thought possible to do the maintenance work without any notable increase in the basic number of maintenance crew.

CONCLUSIONS.

The report described herein may be summed up in the following conclusions:

1) inasmuch as the safety of train running, the riding quality, the stress in each part of track, etc. at high speed operation are now easily ascertainable due to the advancement of the technique of actual measuring on the spot, there are many countries where the allowable maximum speed is decided by the results of such actual measurement;

2) items of actual measurements to be carried out on the car include the transversal thrust, $\frac{\text{transversal thrust}}{\text{wheel load}}$, and the vertical and transversal accelerations, while the items of those to be carried out on the ground include the acceleration, stress and displacement of each part of track. In many

countries, the limit of $\frac{\text{transversal thrust}}{\text{wheel load}}$ is set at about 0.8.

3) the stress on each part of the track and the value of $\frac{\text{transversal thrust}}{\text{wheel load}}$ do not increase very much, even if the speed increases. However, the vibration of rail, that of sleeper and ballast, the transversal thrust, etc. tend to increase with the speed and, therefore, the damage and deterioration of a track structure seem to increase with the speed of trains;

4) the performance of rolling stock has a great effect on the safety of high speed running and the damage of track. The following items are desirable for the track : the bogie of such structure with such inclination of tyre tread as will minimize the hunting; improvement of the brake system of cars to prevent the defects such as the flat on the tyre tread and/or uneven inclination and maintainance of the type tread alawys in a regular condition by keeping the wear allowance lower;

5) in most cases, where the high speed running of trains is concerned, the real superelevation is limited to 70-90 % of the theoretical superelevation for highest speed trains and, its value is fixed at 150-180 mm and the maximum allowable deficiency in superelevation at 60-100 mm in the case of trains run at the highest speed;

6) most railways adopt a cubic parabola transition curve in which the form of running out superelevation is linear. One of the drawbacks of such a transition curve is that the variation of superelevation is not smooth at both ends of the transition curve. To remove this drawback a method is adopted of rounding off the superelevation slope at both ends of the transition curve. Another method is to use a transition curve for which the form of diagram of superelevation is a sine curve and in which the variation of superelevation is smooth at both ends;

7) in many countries the length of a transition curve is determined by the method of expressing it as a function of speed, as in the case of obtaining it from the limit of the variation per second of superelevation or of the variation per second of deficiency in superelevation, rather than by one of expressing it in the multiples of superelevation;

8) a method of prolonging transition curves by omitting the short straight section lying between the two opposite curves is often adopted. In this case, if the circular curves are both short, the short circular curves as well as the short straight section are eliminated by making a series of transition curves with sine curve for running out superelevation on the whole section;

9) in most countries, as a rule, superelevation is made by raising the outer rail, leaving the inner rail as it is, but there are cases where the inner rail is lowered by one half of the amount of superelevation and the outer rail is raised by one half of the amount of superelevation, so that the height of the centre of gravity of cars will not be changed;

10) most crossings at turnouts are of high manganese cast steel or they are built-up bolted rail crossings. But there are, for example, special type crossings in which a gap between the wing rail and the nose rail, and therefore the guard rail, are eliminated by use of a movable nose-rail to obviate the impact against the part forming the gap, the guard rail and the wing rail;

11) it is desirable that a track on which trains run at a very high speed is laid with long welded rails. There are no special requirements for the components of the track structure on such high-speed sections, so far as such components are adaptable to long welded rails. However, it is necessary to keep the track deterioration within the limit of maintenance ability. In designing a track, one of the methods that can be used is to determine the most economical design, taking into account such mainte-

nance cost as correspond to the degree of track deterioration caused by a train load (passing tonnage, train speed and characteristics of rolling stock);

12) important things in the renewal of track on a high speed line are that the work is finished with accuracy, that the effect is durable and that the interventions between two track renewals are made as few as possible. In doing so, it is desirable to completely lift and level the track, packing ballast sufficiently, by using heavy equipment, and to use always new materials for high speed lines;

13) the most important thing in the case of very high-speed operation, is to maintain the track in perfect conditions, keeping within the tolerance the track irregularities as may be measured by an inspection car which is similar in structure to high-speed railcars. The tolerances, of course, should be set smaller than in the case of lower speed operation. As to the measuring items, the variations per metre of track irregularities seem to be more important than the deviations from the specified values;

as the growth of track irregularities largely depends on the loosening and sinking of ballast, it seems to be advantageous to replace the ballast with a solid bed of concrete or with asphalt treated ballast, under good subgrade conditions, though these methods are not extensively used so far;

14) in the case of very high-speed operation, much time is required in restoring the track in a condition good enough to allow the trains proceed without speed restrictions. So, some countries consider that it is preferable when there are many interventions between track renewals, to adopt a maintenance system of periodical general overhaul under which almost all kind of operations can be performed in a series;

15) in the case of high speeds, it is expected that the work amount will increase and periodicity of maintenance will have to be shortened due to the track deteriorations that would grow faster and to the fact that the tolerances would have to be kept down, Against this, however, the track for very high-speed operation, in most cases, is designed to be strong enough to resist deterioration and the efficiency of maintenance work is generally raised by mechanization. Many countries report in this connection that it is not necessary to increase the basic number of their maintenance crew.

STATISTICAL DATA.

Table No 111 — 114.

Table No 31.

TABLE 111. — **Statistical data on the maximum sp**

Item			Unit	Maximum permitted speed (km/h) (exceed)	Australian Rys	C & O Rys	Egyptian Rys	Finnish Rys
Lengths of tracks having these maximum speeds	At the present time		km	100			859	
				110	2 704		322	1 171
				120			416	881
				130		762		
				140				
				150				
				Total	2 704	762	1 597	2 052
	Percentages in relation to the total extended length of track on the main lines for passenger service		%	100			19	
				110	24		7	22
				120			9	17
				130		29		
	In 1938		km	100			416	
				110	370			388
	In 1925		km	110				
Present position	Double track (or more than 2 tracks)		km	100			859	
				110	2 092		322	334
				120			416	340
				130				
				Total	2 092		1 597	674
	Single track		km	110	612			837
				120				541
				Total	612			1 378
	Broad gauge		km	100				
				110				1 171 }(1
				120				881 } m
				130				
				140				
				Total				2 052
	Standard gauge		km	100			859	
				110	2 704		322	
				120			416	
				130		762		
				140				
				150				
				Total	2 704	762	1 597	
	Narrow gauge		km	100				
Divided up according to the kind of traction	At the present time	Electric	km	100				
				110	628			
				120				
				130				
				Total	628			
		Diesel or steam	km	100			859	
				110	2 076		322	1 171
				120			416	881
				130		762		
				140				
				150				
				Total	2 076	762	1 597	2 052
	In 1938	Electric	km	110				
		Diesel or steam	km	100			416	
				110	370			388
				Total	370		416	388

mitted for trains hauled by locomotives.

Indian Rys	Irish Rys	Japanese Rys	Rock Island Rys	Seaboard Rys	Soviet Rys	Swedish Rys	T & P Rys
425	925	1 182	6 693 1 232 483	1 620	30 950 130 1 230	1 449	495 1 290
425	925	1 182	8 408	1 620	32 310	1 449	1 785
	32	14.9		63		31	
425		1 182					715
425							
	396	1 182		110	Double track for the most part	1 449	
	396	1 182		110		1 449	
425	529			1 510			495 1 290
425	529			1 510			1 785
425 (1 676 mm)					30 950 130 1 230 (1 524 mm)		
425					32 310		
	925		6 693 1 232 483	1 620		1 449	495 1 290
	925		8 408	1 620		1 449	1 785
		1 182					
425		1 182			6 800	1 449	
425		1 182			6 800	1 449	
	925	1 182	6 693 1 232 483	1 620	(DL) 6 500 (SL) 17 650 (SL) 130 (DL) 1 230		495 1 290
	925	1 182	8 408	1 620	(DL) 7 730 (SL) 17 780		1 785
425							
		1 182					715
		1 182					715

TABLE 111. - (2).

Item		*Unit*	*Maximum permitted speed (km/h) (exceed)*	*Australian Rys*	*C & O Rys*	*Egyptian Rys*	*Finnish Rys*
Present position as regards maximum load per axle of locomotives used		ton	100 110 120 130 140	22.5	Cooper's E 72 loading	22 22 22	
Present position according to the daily tonnage carried (per km of track and gross tons carried) Sum of sections run over by a traffic of	100 000 tons and more	km	100				
	From 60 000 to 99 999	km	100 110 120			 416	
			Total			416	
	From 40 000 to 59 999	km	100 120			859	
			Total			859	
	From 30,000 to 39 999	km	110 120			322	
			Total			322	
	From 20 000 to 29 999	km	120 130				105
			Total				105
	From 10 000 to 19 999	km	110 120 130				625 448
			Total				1 073
	Less than 10 000	km	110 120 130				546 328
			Total				874
Total time spent on main tracks having these maximum speeds (number of man-hours per km of main track per annum) for all the maintenance work to the plain line and the points and crossings, including transport and handling of materials involved, safety measures for gangmen and working sites, inspection tours, etc.	Maxi-mum	man-hour / km.annum	100 110 120	1 864	870	1 570	
	Mini-mum	man-hour / km.annum	100 110 120	1 243		1 200	

Note : Railways whose speeds do not exceed 120 km/h gave details relating to their lines with the highest speeds existing, but not below 100 km/h.

dian Rys	*Irish Rys*	*Japanese Rys*	*Rock Island Rys*	*Seaboard Rys*	*Soviet Rys*	*Swedish Rys*	*T & P Rys*
20.8	(SL) 21.0 (DL) 15.63	14.4		27.7	(EL) 21.3 (DL) 21.5 (SL) 18.2	15.6 - 17.3	24.2 24.2
		193					
210		910					
210		910					
		79					222
		79					222
215							599
215							599
				175			305
				175			305
				687		1 449	50 609
				687		1 449	659
				758			
				758			
'0(Kalyan-Poona)	847	4 040		364			280
4 350 Bombay-Kalyan)	545	3 410					

TABLE 112. — **Statistical data on the maximum speeds autho**

Item			Unit	*Maximum permitted speed (km/h) (exceed)*	*Australian Rys*	*C & O Rys*	*Egyptian Rys*	*Finn Ry*
Lengths of tracks having these maximum speeds	At the present time		km	100			859	
				110	3 347		322	1 17
				120			416	88
				130		762		
				Total	3 347	762	1 597	2 05
	In 1938		km	100			416	
				110	370			38
				Total	370		416	
	In 1925		km	110				
				Total				
Divided up according to the kind of traction	At the present time	Electric locomotives and railcars	km	100			859	
				110	611		322	
				120			416	
				130				
				Total	611		1 597	
		Diesel locomotives and railcars & steam	km	100				
				110	2 736			1 17
				120				88
				130		762		
				Total	2 736	762		2 0
	In 1938	Electric locomotives and railcars	km	110				
				Total				
		Diesel locomotives and railcars & steam	km	100			416	
				110	370			3
				Total	370		416	3

Note : Railways whose speeds do not exceed 120 km/h gave details relating to their lines with the highest s

TABLE 113. — **Statistical data on the milea**

Item		Unit	*Maximum permitted speed (km/h) (exceed)*	*Australian Rys*	*C & O Rys*	*Egyptian Rys*	*Fin R*
Daily mileage of the diagrammed services without taking into account the overtaking margin at the maximum speeds for the line in question :	Daily mileage	km	100				
			110				
			120		3 565		2 3
			130				
			Total		3 565		2
	Percentage c mpared with the daily mileage of the whole passenger service	%	100				
			110		28		
			120				
			130				

Note : Railways whose speeds do not exceed 120 km/h gave details relating to their lines with the highest

ins hauled by locomotives and for Diesel and electric railcars

ndian Rys	*Irish Rys*	*Japanese Rys*	*Seaboard Rys*	*Soviet Rys*	*Swedish Rys*	*T & P Rys*
425	925	3 447 1 182	1 620		1 449	495 1 290
425	925	4 629	1 620		1 449	1 785
425		1 182				715
425		1 182				715
425						
425						
425		287 1 182			1 449	
425		1 469			1 449	
	925	3 160	1 620			495 1 290
	925	3 160	1 620			1 785
425						
425						
		1 182				715
		1 182				715

ng, but not below 100 km/n.

peed trains, Diesel and electric railcars.

ndian Rys	*Irish Rys*	*Japanese Rys*	*Seaboard Rys*	*Soviet Rys*	*Swedish Rys*	*T & P Rys*
		9 705 9 732	6 150		4 267	
		13 430	6 150		4 267	
		6.8 7.3	31.4		16.7	

ng, but not below 100 km/h.

TABLE 114. — **Statistical data concerning the average speed of**

Railway	*Service* *From*	*To*	*Distance* (km)	*Maximum permitted speed* (km/h)
Australian Rys	Sydney	— Goulburn	221	112.7
	Sydney	— Goulburn	221	112.7
	Sydney	— Albury	642	112.7
	Sydney	— Mt. Victoria	127	112.7
	Sydney	— Mt. Victoria	127	112.7
	Sydney	— Orange	323	112 7
	Sydney	— Newcastle	168	112.7
	Sydney	— Taree	378	112.7
C & O Rys	Detroit	— Grand Rapido	246	127
Egyptian Rys	Cairo	— Alexandria	208	120
	Benha	— Port Said		110
	Cairo	— Assiut	375	100
Finnish Rys	Helsinki	— Hämeenlinna	108	120
	Helsinki	— Hämeenlinna	108	110
	Hämeenlinna	— Helsinki	108	120
	Hämeenlinna	— Helsinki	108	110
	Helsinki	— Tampere	187	110
	Tampere	— Helsinki	187	110
	Helsinki	— Seinäjoki	419	110
	Seinäjoki	— Helsinki	419	110
	Helsinki	— Kouvola	192	110
	Kouvola	— Helsinki	192	110
	Helsinki	— Kuopio	465	110
	Kuopio	— Helsinki	465	110
	Helsinki	— Turku	200	120
Indian Rys	Bombay	— Poona	192	105

trains, Diesel and electric railcars.

rage speed of the fastest runs (including stops) (km/h)			Gross tonnage (ton)	Typical composition of trains and their axle-loads (ton)
Trains	Diesel railcars	Electric railcars		
	76.4		284	
69.2			454	
68.4			454	
		59.5	364	
60.3			418	
51.5			(EL) 418 (SL) 470	
67.6			(EL) 511 (SL) 418	
57.9			454	
80				1 Diesel locomotive 1 Combination mail & baggage 3 Coaches 1 Diner
	87			
	70			
	71			
73.5			440	maximum axle-load 20 ton
	81.0		164	maximum axle-load 14.7 ton
79.0			440	maximum axle-load 20 ton
	84.2		164	maximum axle-load 14.7 ton
	80.0		164	maximum axle-load 14.7 ton
	81.3		164	maximum axle-load 14.7 ton
	76.2		164	maximum axle-load 14.7 ton
	76.2		164	maximum axle-load 14.7 ton
	81.0		164	maximum axle-load 14.7 ton
	79.5		164	maximum axle-load 14.7 ton
	71.5		164	maximum axle-load 14.7 ton
	72.5		164	maximum axle-load 14.7 ton
66.6			266	maximum axle-load 17 ton
60.6				

TABLE 114-(2).

Railway	Service From	Service To	Distance (km)	Maximum permitted speed (km/h)
Irish Rys	Kingsbridge	— Cork	266	113
	Amien ST	— Belfast	181	113
	Amien ST	— Galway	204	113
	Kingsbridge	— Limerick	199	113
Japanese Rys	Ueno (Joban line)	— Aomori	683	100
(Narrow gauge)	Ueno (Tohoku line)	— Sendai	349	100
	Omiya	— Takasaki	75	100
	Tokyo	— Kobe	591	100
	Tokyo	— Kobe	591	110
	Hakodate	— Tomakomai	248	100
	Kobe	— Okayama	143	100
	Kobe	— Hakata	665	100
Rock Island Rys	Chicago ILL	— Tucumcari New Mexico	1 782	145
Seaboard Rys	Richmond, Va.	— Miami Fla.	1 675	127
	Miami Fla.	— Richmond Va.	1 675	127
	Richmond, Va.	— Miami Fla.	1 675	127
	Miami Fla.	— Richmond, Va.	1 675	127
	Richmond, Va.	— Birmingham Ala.	1 190	127
	Birmingham Ala.	— Richmond, Va.	1 190	127
Swedish Rys	Stockholm	— Göteborg	456	130
	Stockholm	— Malmö	617	130
	Stockholm	— Malmö	617	130
	Göteborg	— Stockholm	456	130
	Göteborg	— Stockholm	456	130

Note : Railways whose speeds do not exceed 120 km h gave details relating to their lines with the highest sp

…rage speed of the fastest runs (including stops) (km/h)			*Gross tonnage*	*Typical composition of trains and their axle-loads*
Trains	*Diesel railcars*	*Electric railcars*	(ton)	(ton)
88.8	88.8		400	
83.7	83.7		400	
62	62		400	
64.4	64.4		400	
	65		306	6 passenger motored car (axle load 9.3 - 11.1 ton) 4 passenger trailer (axle load 8 - 8.2 ton) 2 diner trailer (axle load 9.1 - 9.6 ton)
	70		306	
	82		306	
68			615	
		86	441	
	70		306	
		84	336	
	70		306	
84				
87.6			1 900	axle-load Locomotive 27 ton Mail and Baggage 15 ton Coach 15 ton Sleeping car 18 ton Lounge 18 ton Diner 18 ton Observation car 15 ton
90.5			1 900	
91.5			1 900	
89.3			1 900	
77.2			1 500	
70.6			1 500	
98			400	
97			400	
		97	154	
105			400	
		105	154	

g, but not below 100 km/h.

TABLE 31. — Statistical data concer
Decomposition of

Item		Maximum permitted speed (km/h) (exceed)	Australian Rys	C & O Rys	Egyptian Rys	Finnish Rys
According to type of rail	Flat bottomed rails	100			1 330	
		110	2 704		382	1 171
		120			414	881
		130		762		
		140				
		Total	2 704	762	2 126	2 052
	Bull-headed rails	110				
		120				
		Total				
According to weight of rail	More than or equal to 40 kg/m Less than 45 kg/m	110	499			1 171
		120				643
		130				
		Total	499			1 814
	More than or equal to 45 kg/m Less than 50 kg/m	100			1 330	
		110	354		217	
		Total	354		1 547	
	More than or equal to 50 kg/m Less than 55 kg/m	100				
		110	1 851		165	
		120			414	96
		130				
		140				
		Total	1 851		579	96
	More than or equal to 55 kg/m	100				
		110				
		120				142
		130				
		140				
		Total				142
According to age of rail	Less than or equal to 10 years	100			120	
		110	740			608
		120				822
		130				
		140				
		Total	740		120	1 426
	10 to 15 years	100			10	
		110	403		165	267
		120			414	
		130				
		Total	403		589	267
	15 to 20 years	100				
		110	32			30
		120				
		130				
		Total	32			30

equipment of the lines.
ulative length of the lines.

Length of lines (km)

Indian Rys	*Irish Rys*	*Japanese Rys*	*Seaboard Rys*	*Soviet Rys*	*Swedish Rys*	*T & P Rys*
343	597	1 182		30 950 130 1 230	1 449	495 1 290
343	597	1 182		32 310	1 449	1 785
82	725					
82	725					
343	1 009				556	
343	1 009				556	
82	313					
82	313					
		1 182	349	22 700 130 1 190	893	
		1 182	349	24 020	893	
			1 271	8 250 40		495 1 290
			1 271	8 290		1 785
	219	792	595	30 950 130 1 230	690	
	219	792	595	32 310	690	
	51	22	715		185	
	51	22	715		185	
	42	34	233		175	
	42	34	233		175	

TABLE 31. - (2).

Item			*Maximum permitted speed (km/h) (exceed)*	*Australian Rys*	*C & O Rys*	*Egyptian Rys*	*Finnish Rys*
		More than 20 years	100			1 200	
			110	1 529		217	266
			120				59
			130				
			Total	1 529		1 417	325
According to age of last complete renewal of sleepers		Less than or equal to 10 years	100			120	
			110	1 111		165	
			120			414	
			Total	1 111		699	
		10 to 15 years	100			10	
			110	595			
			Total	595		10	
		15 to 20 years	110	48			
		More than 20 years	100			1 200	
			110	950		217	
			Total	950		1 417	
Short rails	According to length	40 to 60 m	100	1 594		25	
			120			213	
			130				
			Total	1 594		238	
		20 to less than 40 m	100			150	
			110				42
			120				66
			130				
			Total			150	108
		15 to less than 20 m	100			49	
			110			140	1 027
			120			200	800
			130				
			Total			389	1 827
		10 to less than 15 m	100			1 130	102
			110			217	15
			120				
			130				
			140				
			Total			1 347	117
	According to whether joints are staggered or not	Staggered	100				
			110	1 272			
			Total	1 272			

ndian Rys	*Irish Rys*	*Japanese Rys*	*Seaboard Rys*	*Soviet Rys*	*Swedish Rys*	*T & P Rys*
	1 010	334	77		399	
	1 010	334	77		399	
	650	1 182				
	650	1 182				
	132					
	132					
	108					
	432					
	432					
					300	
					300	
		1 071			675	
		1 071			675	
	1 322			12.5 m or 25 m	330	
	1 322				330	
425						
425						
	386	20				
	386	20				

TABLE 31. - (3).

Item			Maximum permitted speed (km/h) (exceed)	Australian Rys	C & O Rys	Egyptian Rys	Finnish Rys
		Not staggered	100			1 329	
			110	322		382	1 171
			120			413	881
			130				
			140				
			Total	322		2 124	2 052
Long rails (over 100 m)			100			1.0	
			110	1 110			
			120			1.0	
			130				
			140				
			Total	1 110		2.0	
According to kind of sleepers	Short rails	Wood	100			829	
			110	1 594		357	
			120			253	
			130				
			Total	1 594		1 439	
		Reinforced concrete + Longitudinal plates					
		Prestressed concrete	100				
			110				
			120				
			Total				
		Steel	100			500	
			110			25	
			120			160	
			Total			685	
	Long rails	Wood	100			1.0	
			110	1 110			
			Total	1 110		1.0	
		Reinforced concrete + Longitudinal plates					
		Prestressed concrete	100				
			110				
			120			0.5	
			130				
			Total			0.5	
		Steel	120			0.5	

ndian Rys	Irish Rys	Japanese Rys	Seaboard Rys	Soviet Rys	Swedish Rys	T & P Rys
		1 051				
	936			30 950		
				130	1 305	
				1 230		
	936	1 051		32 310	1 305	
		111				
					144	
		111			144	
		866				
	1 290					495
						1 290
					1 305	
	1 290	866			1 305	1 785
		205				
	32					
	32	205				
		111				
					144	
		111			144	

TABLE 31. - (4).

Item			*Maximum permitted speed (km/h) (exceed)*	*Australian Rys*	*C & O Rys*	*Egyptian Rys*	*Finnish Rys*
According to number of sleepers (Number of sleepers per km)	1 200 to less than 1 500 pieces/km		110				
	1 500 to less than 1 700 pieces/km		100			1 330	
			110	2 704		382	1 171
			120			414	881
			130				
			Total	2 704		2 126	2 052
	1 700 to 2 000 pieces/km		100				
			110				
			120				
			130		762		
			Total		762		
According to type of fastening	Rigid fastening	Without base-plates	100				
			110	1 610			
			120				
			130				
			140				
			Total	1 610			
		With base-plates	100			1 280	
			110	1 078		382	
			120			414	1 104
			130				407
			140				
			Total	1 078		2 076	1 511
	Elastic fastening	Without base-plates	100				
			110				
			120				
			130				
			140				
			Total				
		With base-plates	100			50	
			110	16			
			120				67
			130				475
			140				
			Total	16		50	542

Note : (1) The maximum speeds given here refer solely to trains hauled by locomotives.
(2) Railways whose speeds do not exceed 120 km/h gave details relating to their lines with the highest speeds existing, but not below 100 km/h.

Indian Rys	Irish Rys	Japanese Rys	Seaboard Rys	Soviet Rys	Swedish Rys	T & P Rys
	1 322					
					1 449	
					1 449	
		1 182				495 1 290
		1 182				1 785
	1 290	601				495 1 290
	1 290	601				1 785
	32	316				
	32	316				
		265			1 449	
		265			1 449	

NEW BOOKS AND PUBLICATIONS.

[385 (02]

Directory of Railway Officials and Year Book, 1961-1962. London : Tothill Press Ltd., 33, Tothill Street, Westminster, S.W. 1. — One volume of 656 pages (8 1/2 × 5 1/2 inches), (Price 60 s. net.)

The Directory of Railway Officials and Year Book, 1961-1962, reaches with the present volume its 67th year of publication.

The first edition was compiled from official sources in 1895. The present edition containing 656 pages of text includes the general index and the personal index to railway officials, a noteworthy feature of the volume.

Railway developments throughout the world, including the rapid extension of electric and Diesel traction and also the construction of new railways in less developed countries, have necessitated numerous changes with this edition than occurs normally from one year to the next.

Amongst the new features of the present volume are the entries relative to Ministries of Transport and similar Government departments in the principal countries.

Extensions of electrification in Great Britain, France, India, Italy, Japan, etc., have also been recorded.

All other features have also been revised to date but have not needed drastic overhaul.

This edition should prove as valuable as its predecessors. It will be greatly appreciated by all those concerned with railway matters.

A. U.

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